DESIGNING FOR THERMAL COMFORT IN NATURALLY VENTILATED AND AIR CONDITIONED BUILDINGS IN SUMMER SEASON OF GHADAMES, LIBYA.

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April 2000

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This thesis is submitted in partial fulfilment
Of the requirements of De Montfort University for the degree of
Doctor of Philosophy

April 2000

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بسم الله الرحمن الرحيم

SŪRAH LXXXIV

Al-Inshiqāq, "The Sundering," takes its name from a word in verse 1. An early Meccan sūrah.

THE SUNDERING

Revealed at Mecca

In the name of Allah, the Beneficent, the Merciful.

1. When the heaven is split asunder
2. And attentive to her Lord in fear,
3. And when the earth is spread out
4. And hath cast out all that was in her, and is empty
5. And attentive to her Lord in fear!
6. Thou, verily, O man, art working toward thy Lord a work which thou wilt meet (in His presence).
7. Then whoso is given his account in his right hand
8. He truly will receive an easy reckoning
9. And will return unto his folk in joy.
10. But whoso is given his account behind his back,
11. He surely will invoke destruction
12. And be thrown to scorching fire.
13. He verily lived joyous with his folk,
14. He verily deemed that he would never return (unto Allah).

(٨٤) سورة الانشقاق مكية وآياتها ٢٥ نزلت بعد الانفطار

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

إِذَا السَّمَاءُ انشَقَّتْ ﴿١﴾ وَأَذِنَتْ لِرَبِّهَا وَحُقَّتْ ﴿٢﴾
وَإِذَا الْأَرْضُ مُدَّتْ ﴿٣﴾ وَأَلْقَتْ مَا فِيهَا وَتَخَلَّتْ ﴿٤﴾
وَأَذِنَتْ لِرَبِّهَا وَحُقَّتْ ﴿٥﴾ يَا أَيُّهَا الْإِنسَانُ إِنَّكَ كَادِحٌ
إِلَىٰ رَبِّكَ كَدْحًا فَمُلَاقِيهِ ﴿٦﴾ فَأَمَّا مَنْ أُوتِيَ كِتَابَهُ
بِيَمِينِهِ ﴿٧﴾ فَسَوْفَ يُحَاسَبُ حِسَابًا يَسِيرًا ﴿٨﴾
وَيَنقَلِبُ إِلَىٰ أَهْلِهِ مَسْرُورًا ﴿٩﴾ وَأَمَّا مَنْ أُوتِيَ كِتَابَهُ
وَرَاءَ ظَهْرِهِ ﴿١٠﴾ فَسَوْفَ يَدْعُو ثُبُورًا ﴿١١﴾ وَيَصْلَىٰ
سَعِيرًا ﴿١٢﴾ إِنَّهُ كَانَ فِي أَهْلِهِ مَسْرُورًا ﴿١٣﴾ إِنَّهُ ظَنَّ أَن

To Mom, Brothers, My Wife and children and all my family who love always encouraged me and supported my work. Also, to any one seeking more knowledge in this field.

Mansour Ali Ealiwa

Abstract

The outdoor climate of an area has a significant impact on housing and urban fabric as a whole, and the more extreme a climate, the more necessary it becomes to respond to it. Thus the climate should be regarded as a significant modifier of the built environment; thermal discomfort within building environments is a prevalent and significant issue throughout the developed and developing countries. There is considerable disagreement in the research community concerning whether comfort standards developed in the climate of North America and Europe are appropriate for use in other countries with more extreme climatic conditions.

This research focuses on designing for the conditions of thermal comfort in hot dry climate regions. The research reports field surveys in both naturally ventilated (NV) buildings and air-conditioned (AC) buildings in summer season, with reference to Ghadames in Libya. This involves objective measurements and subjective questionnaire study with a view to testing the validity of the established thermal comfort models: Fanger's PMV model and the Adaptive model. It reviews the results from the field survey within those two types of buildings in the summer seasons of 1997 and 1998, which experiences the hot-dry climate of North Africa. It shows how the residents responded to the environmental conditions, social needs, and architectural character such as building design and thermal mass. The method of study and analysis are critically described.

The subjective data was collected and tabulated by using questionnaires, which have been widely used and shown to be effective, to determine people's votes through scales modified especially for this purpose. Questionnaires were collected from households of 60 buildings: 30 old NV buildings and 30 new AC buildings involving a total of 270 participants from both types of buildings. The questionnaires compare the significance of the thermal sensation, the thermal comfort, and the preference scales of each type of building.

The objective survey consisted of 19 observations of empirical data (in the 9 old NV buildings, and in the 10 AC new buildings) to validate the performance of the current thermal comfort indices. The results show that the PMV model is not valid, unless modified, for predicting the thermal comfort in old buildings, in Ghadames oasis, Libya. Thus a modification is proposed. However, the results from modern air-conditioned buildings have shown that there is good agreement between Fanger's model and the actual mean vote (AMV) values reported by the occupants in these buildings.

The results from the present study show also that the neutral temperatures in old and new buildings are 31.6°C and 29.4°C respectively. The adaptive model, which is developed by Auliciems (1983), is shown to be valid, without modification, for predicting the thermal comfort of sedentary occupants in such environments.

The results indicate that the construction of residential dwellings using traditional methods is more conducive to the climatic conditions of hot-dry climates and suitable for the cultural requirements and life style of the occupants. Human thermal comfort was assessed using the adaptive model, to show that the climate and personal behaviour have a significant impact on human comfort perception and building design.

Acknowledgements

The first verses reviled on Prophet Mohammed in the Holy QURAN, was '*Read*'. Therefore seeking knowledge is becoming as compulsory on any Moslem male or female. Therefore, first and for most, I would like to thank 'ALLAH', that he is the one who give me the gaudiness and strength to go through above all of difficulties which I have faced during my study. As a matter of fact, this research was supported with funding from the Higher Municipality of Education in Libya, and was undertaken within the Libyan Interests Section in London, and more recently, during the field survey, the Faculty of Engineering at the Sabha University, Libya (Libyan Arab Jamahiriya). I know that this study would not have been possible without encouragement, inspiration and supporting from so many people back home in Libya. Therefore to all of them, I would like to acknowledge their contribution, and I hope that Allah will give me the ability to give back something to my people and my country. I hope that this kind of knowledge will build a good aggregate platform for those who are seeking to gain more knowledge in this field.

I would like to thank my director of studies, Dr. Roy Seden and to supervisor Dr. Ahmed Taki (De Montfort University in Leicester, UK), whose support, sound guidance, and meticulous attention to detail throughout this research have been greatly appreciated. I would also like to thank my third supervisor Professor Andrew Howarth (Nottingham University, UK), whose complimentary background ensured a varied and balanced approach to my research. All three of them, we work as a very good team. I am very grateful to them whose useful comments have helped immensely in the development of the on-going research until the last moment. I am indebted to three of them for their enlightening discussions and for spending many hours advising on the direction of the research and later checking the accuracy of my work. I would like also to thank all of the staff at the Leicester School of Architecture in De Montfort University. Among those, especial thanks to Professor George Henderson (head of the School), Dr. John Ebahon, the secretary Mrs Audrey Burbank, and Mr. Sudhir, for their moral support and encouragement during all of these three years of struggling of my research.

It is difficult for me to find words which adequately express my feelings of thanks towards my Uncle Mr Mohammed Abu-Alqasim, my Brother Abdul-Allah, my Mother and the rest of my family, who give lots of encouragement during my study. Last but not least, my wife Zainab and my children Zahra, Ali, Nour, Tasneem and Mohammed, whose incredible patience and unfailing loving supports have, without doubt, ensured completion of this thesis work. The Local residents of Ghadames in Libya deserve special thanks for their excellent help and hospitality over the entire period of the fieldwork. Special thanks also to engineer Adel Al-Theiny in Ghadames, my nephew engineer Hafid Mohammed, and my brother Haj Ibrahim Ealiwa for their assistance during the fieldwork. They all truly provided me the moral and physical support. Finally, my thanks go also to all my colleagues and friends, Libyan and non-Libyan from all over the world, whose I meet them at De Montfort University in Leicester, UK. Among those, Amer Hamzah from Malaysia, and Roger Amboga from Uganda. I enjoyed very much those three years which we spent struggling researching and seeking more knowledge to be fulfilling for the degree of Ph.D.

Chapter Three: THERMAL COMFORT AND THE BUILT ENVIRONMENT

Chapter Four: FIELD SURVEY: RESEARCH METHODOLOGY

Chapter Five: GHADAMES CASE STUDY: BACKGROUND

Chapter Six: FIELD SURVEY: PROCEDURE AND OVERALL SUBJECTIVE RESULTS

Chapter Seven: DATA ANALYSIS AND INTERPRETATION: Assessing Thermal Comfort

Chapter Eight: THE EFFECT OF OUTDOOR CLIMATE AND ACCLIMATISATION ON HUMAN PERCEPTION OF THERMAL COMFORT

Chapter Nine: DEVELOPING THE PROCESS TOWARDS THERMAL COMFORT AND PREFERENCE

Chapter Ten: CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

Nomenclature

AC	Air-conditioning	
As	Surface Area	m^2
ASHRAE	American Society of Heating, Refrigerating and air-conditioning Engineers.	
AMV	Actual Mean Vote	
A	Temperature field.	
B	Air-flow field.	
C	Night Ventilation, etc.	
CIBSE	Chartered Institute of Building Service Engineers	
E_{sw}	Sweat Secretions.	
ET*	Effective Temperature indice.	
ISO	International Standards Organisation	
Activity	Metabolic Rate	W/m^2 or met
M.B.R.T	Main bedroom temperature	°C
NV	Naturally Ventilated	
P_a	Water Vapour Pressure	p_a
P_{sa}	Saturated Vapour Pressure	kP_a
PMV	Predicted Mean Vote	
PPD	Predicted Percentage Dissatisfaction	
Rh	Relative Humidity	%
Rcl	Clothing Value	m^2 K/W or clo
SET	Standard Effective Temperature indice.	
t_b	Body Temperature	°C
t_g	Globe Temperature	°C
t_{in}	Inside Air Temperature	°C
t_{mr}	Mean Radiant Temperature	°C
t_n	Neutral Temperature	°C
t_{out}	Outside Air Temperature	°C
t_s	Surface Temperature	°C
t_o	Operative Temperature	°C
t_{sk}	Skin Temperature	°C
Tp	Thermal Preference.	
TS	Thermal Sensation.	
TS_B	Thermal Sensation of Bedford.	
v_a	Air Velocity	m/s
W	Skin Wettedness.	
r	Correlation Coefficient	(see equations and tables in chapters 7 and 9)
a, b	Constants	(see equations and tables in chapters 7 and 9)
X	Building	
Y	Personal	
☼	Sample for selected building	

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Chapter One:

GENERAL INTRODUCTION

"To design is to plan and to organise, to order to relate and to control in short it embraces all means of opposing disorder and accident. Therefore, it signifies a human need and qualifies man's thinking and doing". Albers, J, as quoted by Bucher, F. (1961: p 75).

1.1 General Overview

One of the fundamental reasons for constructing a building is to create shelter from the prevailing environmental elements. The desire to keep dry and warm/cool (depending on climate) has generated a variety of architectural forms which have evolved to increase the impermeability of the building envelope to natural conditions and, through environmental engineering, allow us to create our own interior environmental conditions.

Space and the physical environment in which we are living, have an enormous bearing on our comfort. Since earliest times, man has reacted to his environment by developing his living place in balance with Nature, creating shelters built of the materials offered up by the landscape. Traditional architecture is considered as one of the clear manifestations of man-environment interactions, in which climate has a large effect on the architectural form. Thus the harsh environmental condition in hot-dry climate regions, such as the one in North Africa, has influenced the social organisation and culture of the people through many generations. The inhabitants' experiences have played a fundamental part in shaping the design and character of traditional buildings and the associated planning of their towns.

The climate of an area has a significant impact on buildings and the urban fabric as a whole. The more extreme the climate is, the more necessary it becomes to respond to it. According Culjat and Erskine (1983), as quoted in Pressman (1987: p49), "the influence of climate has been largely ignored in project planning and policy development. Although the influence of climate is not, nor should it be, deterministic, it should nevertheless act either as a facilitator or as inhibitor of certain types of cultural adaptation expressed through the built form. Climate must be regarded as a significant modifier of the built environment...". Thus it is essential that climatic factors are taken into consideration in building design to ensure that they suit the people who will inhabit them (BRE 1980; Gappert 1987). Whilst these micro level considerations are made, the macro scale urban patterns should also be examined from a climatic perspective with the aim of creating a climate responsive environment. It has been mentioned that "As we are no longer living in an era of cheap and plentiful land and energy, we shall have to plan and manage our cities using a model of urban settlement that is highly integrated with the natural forces" (Pressman 1987: p50). Climate, buildings, and urban design are interrelated and ensuring a fair balance of these factors is essential for the comfort of man.

Thermal comfort has been the topic of much field and chamber research for over one hundred years, but little is known about thermal comfort in North Africa generally and in Ghadames oasis in Libya specifically. Are current methods used to establish comfort conditions appropriate for people who live in the hot-dry climate? and to what extent do deviations from comfort conditions affect the degree of discomfort of people in such environments? The answer to these questions may depend on the type of the buildings, but this is also not known. The aim of this field survey presented in this research was to address the above questions for different types of residential buildings, old and new. The results are intended to provide insight into thermal comfort issues or standards, and paradigms relevant to an extreme hot environment.

There is considerable disagreement in the research community concerning whether comfort standards developed in the temperate climates of North America and Europe are appropriate for use in other countries with more extreme climatic conditions. Some researchers, who mainly employ thermal chamber methods, have found that thermal comfort is independent of geographical location criterion, while others using the field test method have found that thermal comfort is dependent on local average ambient conditions. (Abdulshukor 1993, and de Dear 1994). However, this research was undertaken primarily to study the influences of the indoor and outdoor climate on human response and building design in terms of thermal comfort, and the ways in which such knowledge could be synthesised to assist architects in the course of the design process. There has been little such research for the hot-dry climates in North African countries. Climate related research in the field of architecture and building science needs to be initiated and sustained in hitherto neglected regions, and this research seeks to address this matter.

1.2 Context

This investigation is concerned with building environments in a hot climate, with particular reference to Libya. It is a comparative study of both old buildings with a naturally ventilated courtyard system and modern buildings with an air-conditioning system. The research considers the effectiveness of design and environment in buildings in terms of thermal comfort to achieve thermal satisfaction for the occupants. It examines these issues, and derives its hypotheses from previous research, which has expanded understanding of the particular nature of this subject. This introductory chapter deals with a number of issues:

- It outlines the identification of the problem (1.3.1).
- It sets out the aims and objectives of the research (1.3.2).
- It highlights the limitation of study (1.3.3).
- It highlights the research design and method (1.3.4).
- It provides the research framework (1.3.5).
- It addresses the significance of findings (1.3.6).

1.3 Structure of Research Project

1.3.1 Statement of the Problem

At present, most developing countries have adopted the 'developed' countries' modern way of life, embracing their products and production process. In the building and construction industry, this vision of urbanisation is expressed vividly through luxurious buildings by using imported building materials, and construct un-necessarily large internal spaces which are unused and unsuitable for the indigenous society. These unfortunately impact negatively on the building construction cost. Therefore, the government authorities of these countries have tended to introduce modern constructed materials together with new modern ideas of building design from the Western countries. These new ideas, and modern equipment and materials, may have satisfied government policy and building needs, but they failed to achieve satisfactory thermal comfort levels and create a multitude of building indoor environmental problems (Shawesh, 1992). Thus, tackling these issues and their effect on the building's environmental problems is really crucial. "Climate must be regarded as a significant modifier of the built environment" (Pressman, 1987: p 49); "The more extreme the climate is, the more necessary it become to respond to it." (Culjat and Erskine, 1983, as quoted in Pressman, 1987: p47).

Building design for hot-dry climates is considered an important and complex task. Shawesh (1992) stated that traditional buildings in this climate perform well thermally and provide the necessary comfort for the occupants, while the new type of building has not satisfied the climatic condition, nor has it answered the religious or social trends in demand. Many lessons could be learnt from the traditional architectural design forms, based on people' past experience of many generations. These experiences are based on their responding to their environment as physical forces that acted upon them, in order to adapt themselves to life within such a severe and harsh climate. Rapoport (1981: p21) states that

> "Housing is essential, it is a basic human need and central component in our daily lives. For most groups in our culture the dwelling is very central. ... most time is spent in it; it is one's most valuable possession. It has highest effective meaning and it is increasingly the locus of much recreation previously occurring elsewhere".

However, if the shelter fails to provide sufficient of comfort level together with its occupants' social requirements, the thermal comfort, health and morale of the occupants could be critically affected. The design of any type of building reflects certain beliefs and attitudes. Shawesh, (1992) stated that there were many complaints in Ghadames City in Libya from users of modern buildings in terms of lack of comfort based on overheating and cooling. He mentioned also that in the old part of that city, where the traditional houses with courtyards are densely clustered together, this resulted in minimum solar exposure on internal and external walls.

Some researchers such as Ahmed (1985), Olgyay (1980); Szokolgy (1980); Evans (1980) and Cook (1980) have stated that the courtyard is highly recommended for use in hot dry climates.

As well as drawing on experience of other research, the Author should state that he has been a resident living in the desert region. In addition to his experience, the literature reviews of some other researchers such as Shawesh (1992 and 1996), Buchanan (1975), Bukamur (1985), El-Fortia (1989), etc., who are stated that people in such regions are suffering from uncomfortable indoor environment (see chapters 2 and 5). Climatically, the development of modern design has led detached buildings to be exposed directly to solar radiation with windows unprotected from the sun, which creates indoor environment problems. To counter this problem, windows are closed during the hottest part of the day, which is between 12:00 PM and 17:00 PM in summer, and it is not therefore possible to generate the same level of natural ventilation and shadow as a courtyard can provide. Thus the ultimate problems based on the literature reviews for a hot-dry climate are:

1. Building design;
- Lack of designing temperature for thermal comfort in such environment
- Streams of complaints regarding thermal discomfort from people who live in new buildings, which are supplied with air-conditioning systems.
- Lack of thermal comfort studies in such environments (North Africa). See Figure 1.1, which shows literature review by de Dear (1994) that indicated an adequate database for thermal comfort in different places except Africa generally and North Africa specifically.
2. The validity of the PMV and the Adaptive thermal comfort models have not been assessed or tested in such extreme hot-dry climate before.
3. Socio-cultural issues, such as;
- Demand of religious trends.
- Lack of privacy and organisation of space.
- The gap between traditional and contemporary architecture.

Accordingly, it is of great value to tackle the above mentioned problems which are very important for the life of people living in the desert region. Therefore, the project focus is to enhance the internal environment in their buildings in the hot-dry climes based on typically accessible parameters, especially natural ventilation and courtyard geometry.

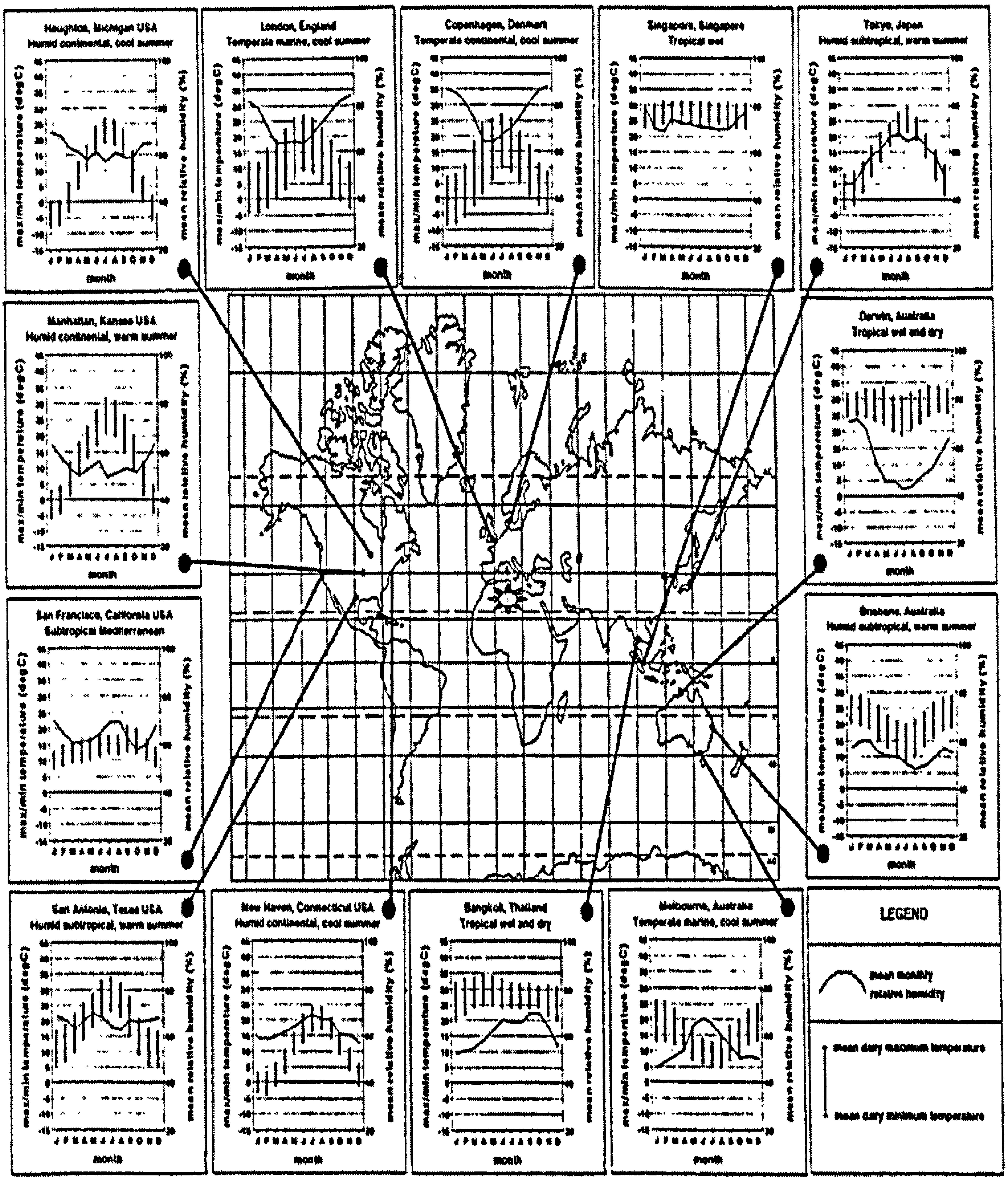


Figure 1.1: Climatic classification of places referred to in the literature review by de Dear (1994: 109).

1.3.2 Aims and Objectives

The primary aim is to identify and study two building environments in Ghadames oasis; one with air conditioning systems and the other with naturally ventilated courtyard systems. This will provide technical advice and guidance for use by designers of courtyard buildings to achieve satisfactory internal environment for the occupants. A wide range of literature reviews will be undertaken of building design types and their suitability in Libya generally, and in Ghadames Oasis specifically, in order to underline the research area, together with further literature reviews on thermal comfort in order to understand its concepts. The experience of the Author on living in the hot-dry climate regions will help to identify the drawbacks and deficiencies that cause the current building problems. These problems will be considered in terms of thermal comfort issues by seeking to respond adequately to human needs and their indoor environmental requirements in order to minimise, if not to solve, their discomfort. The climate of the desert of Libya together with the Islamic social way of life will be used as an example in this research to underline a methodology by which courtyard houses can be modified to achieve thermally comfortable indoor climates. Therefore, through the field survey of the selected area, the following points outline the aims and general objectives of the research:

1. To provide a distinctive new set of data relating to thermal comfort
2. To assess human thermal comfort together with building environment (subjective and objective measurements) in the summer seasons at the case study of Ghadames in Libya. This measurement will be conducted in both types of buildings:
   - Old buildings with natural ventilated system (NV).
   - New buildings with air-conditioning system (AC).
3. To test the applicability of the two existing thermal comfort models in a hot-dry climate in such an environment and in such a culture. Then, to develop a process towards the thermal comfort and preference, and modify the current comfort models where necessary based on practical measurements, such as;
   - Fanger's PMV model in the form of ISO 7730 standard (1995).
   - The Adaptive model.
   - To explore relationships between outdoor and indoor temperatures for human behaviour.

4. To determine design conditions to achieve human thermal comfort for both types of buildings (NV and AC) in such environments, in order to bridge the gap between traditional and contemporary architecture and to make design recommendations. As well as to provide guidelines for future designing of buildings in such hot-dry regions, as regards comfort requirements.

From the result of the case study, this research also hopes to identify reliable and comfortable building design temperatures to live in such environments. Furthermore, it hopes to identify the cause of complaints regarding thermal discomfort, as well as the needs for enhancement, which come from the residents of the newly constructed buildings, which are air-conditioned.

1.3.3 Limitation of Study

In carrying out the study a number of limitations and constraints have been identified. First of all the research was limited by the available time and equipment, which confined the prospective areas of designation. The research does not intend to analyse the individual rooms and physical responses of the occupants (e.g. skin temperature) but to analyse their social life and personal acclimatisation with regard to thermal comfort. Due to the limited time and resources available only one comprehensive case study at the summer season was carried out in a typical Libyan town, and only two types of buildings were chosen to investigate the thermal comfort issues. Lengthy discussion of the outdoor climate interaction with the indoor thermal environment effects on the behaviour of the residents (e.g. social life of the occupants and their personal acclimatisation), is provided in order to discuss the case in question. Wherever possible primary data from the field survey will be used, but in the event of non-availability secondary data from the literature reviews has been used instead to justify the issues.

In spite of all these limitations, and circumstance permitting, it is considered that the case study and survey undertaken are original and have provided new knowledge by testing the validity of both Fanger's PMV and Adaptive thermal comfort models, as well as widening the range of database of thermal comfort.

1.3.4 Research Design and Methods

A comparative approach has been employed in this research based different samples of occupants who are lived in traditional architectural design buildings using naturally ventilated systems and who are lived in modern architectural design buildings using air-conditioned systems at Ghadames Oasis in Libya. The main data were therefore collected through a field survey conducted especially for this research by the Author himself in summer seasons 1997 and 1998.

A case study of Ghadames oasis objectively highlights the main problems within different kinds of indoor and outdoor climates. For this purpose a field survey in Ghadames was carried out in selected buildings randomly which typified building-forms in that town. The survey sought to determine the actual threats and risks the old buildings are facing in relation to the development of the town. The survey then sought to provide enough data in order to assess the validity of two world-wide thermal comfort models, i.e. the PMV and adaptive models, and then analyse the results in order to draw conclusions.

The research therefore has been designed to address the previous problems in terms of thermal comfort in both traditional buildings with naturally ventilated systems, and the contemporary buildings with air-conditioned systems. Two kinds of surveys were conducted in order to design for this research project:

a) 'Subjective study'; using a questionnaire to identify and uncover deficiencies in terms of resources, and identify other causes of discomfort of the occupants in each type of building, in order to rectify the problems if any and provide recommendation for improvement.

b) 'Objective study'; using an experimental method to measure the basic environmental parameters, such as air temperature, air velocity, the mean radiant temperature, etc. These parameters have been used to assess the validity of both the PMV and the adaptive models in such a hot-dry climate as in Ghadames.

The conceptual progress through four main stages has been organised for the study, in order to develop this research, as indicated in Figure 1.2. In the first stage, the problems will be identified, and the objectives set as described in chapter one. This is based on the literature background of the thermal comfort concepts, and the building types in Libya, as detailed in chapters two and three. In the second stage, the actual field-work in buildings is outlined, namely the general survey methodology in chapter four, and the background for field survey in chapter five.

The third stage highlights the main part of this research. In this stage, the procedure of the field survey is highlighted together with overall subjective results. In chapters six and seven, results are analysed and comparisons are made between the traditional and contemporary buildings, in order to test the validity of both the PMV and Adaptive thermal comfort models. Following that, chapters eight and nine discuss and evaluate the importance and the effect of the outdoor climate on the human social life and their personal acclimatisation. The two models (PMV and Adaptive) are combined in order to modify the existing PMV model to be used to assess thermal comfort in an extreme hot climate as in Ghadames region.

Finally, the fourth stage highlights the conclusions, recommendations and suggestions for further research in chapter ten. In the following section, the research framework is outlined in more detail.

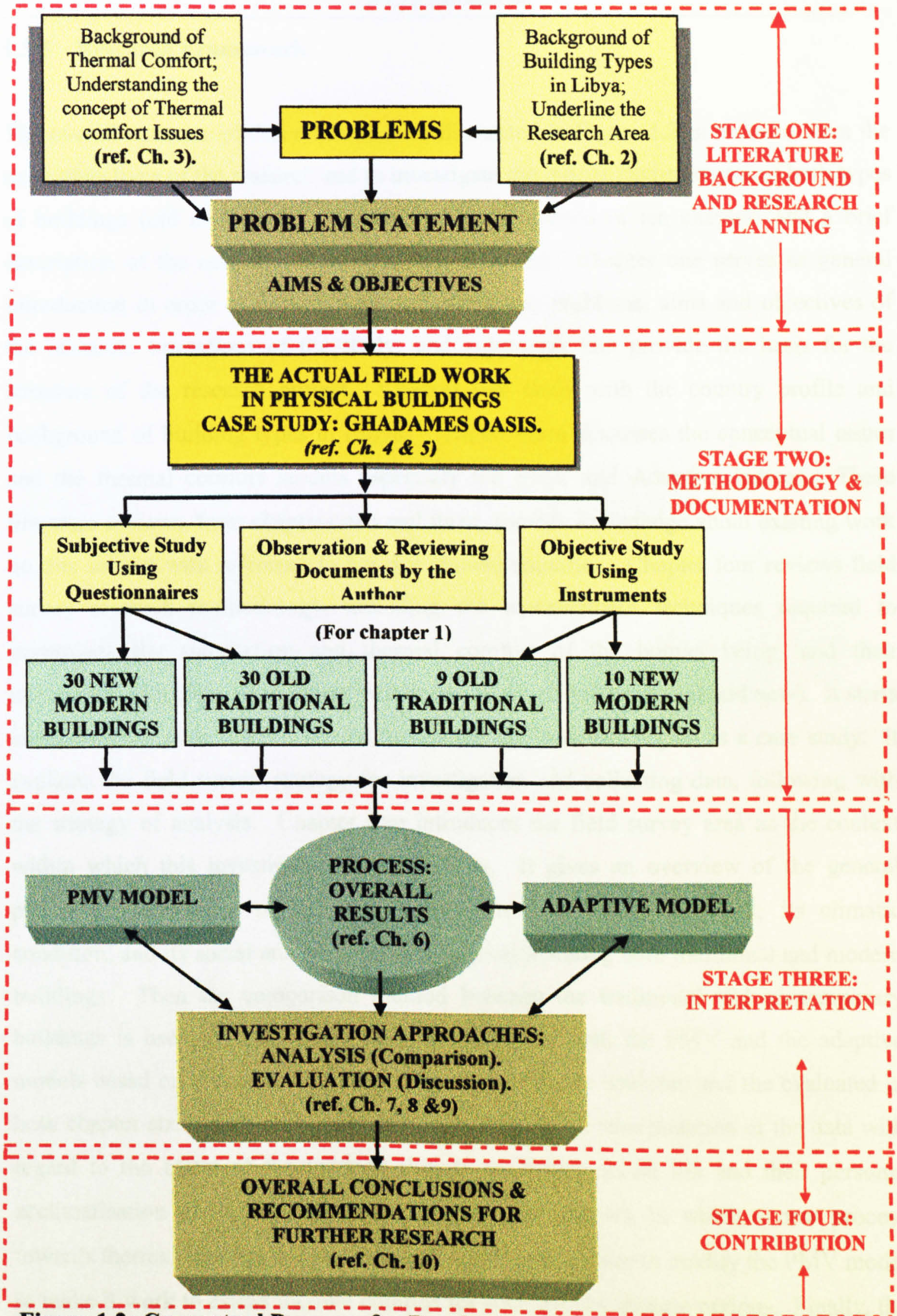


Figure 1.2: Conceptual Progress for Developing the Research Strategy

1.3.5 Research Framework

The overall structure of this research is as illustrated in Figure 1.3 in order to meet the main objectives of the research and to investigate the indoor environments of both types of buildings (old and new). This research is composed of ten chapters and a brief description of the contents of the chapters followed: Chapter one serves as general introduction in order to present a general overview; problems; aims and objectives of the research; limitations of the study; and arguments that provide the basis for the structure of the research project. Chapter two deals with the country profile and background of building types in Libya. Chapter three discusses the conceptual issues and the thermal comfort models especially the PMV and Adaptive indices. These literature reviews, from chapters two and three, provide knowledge about existing work on this subject with reference to hot-dry climate countries. Chapter four reviews field survey research methodology, including the measurement techniques required to investigate the satisfaction and thermal comfort of the human being, and their interaction with their environment within two types of buildings (old and new). It starts addressing the main reasons behind the choice of Ghadames region as a case study. It explains the field survey strategy for investigation and collecting data, following with the strategy of analysis. Chapter five introduces the field survey area as the context within which this investigation is carried out. It gives an overview of the general picture of Ghadames region: its location; its historical background; its climatic condition; and its social and building characteristics among both traditional and modern buildings. Then the comparison method between the traditional and contemporary buildings is used to analyse and test the validity of both the PMV and the adaptive models based on the collected data. Then the results are analysed and the evaluated in both chapter six and seven. Chapter eight highlights the interpretation of the data with regard to the effect of the outdoor climate on human social life and their personal acclimatisation of thermal comfort. Chapter nine follows, in which a new process towards thermal comfort and preference is addressed in order to modify the PMV model to make it work to assess thermal comfort for such hot/dry climate regions. Finally, the findings are presented through conclusions, recommendations and further research as described in chapter ten.

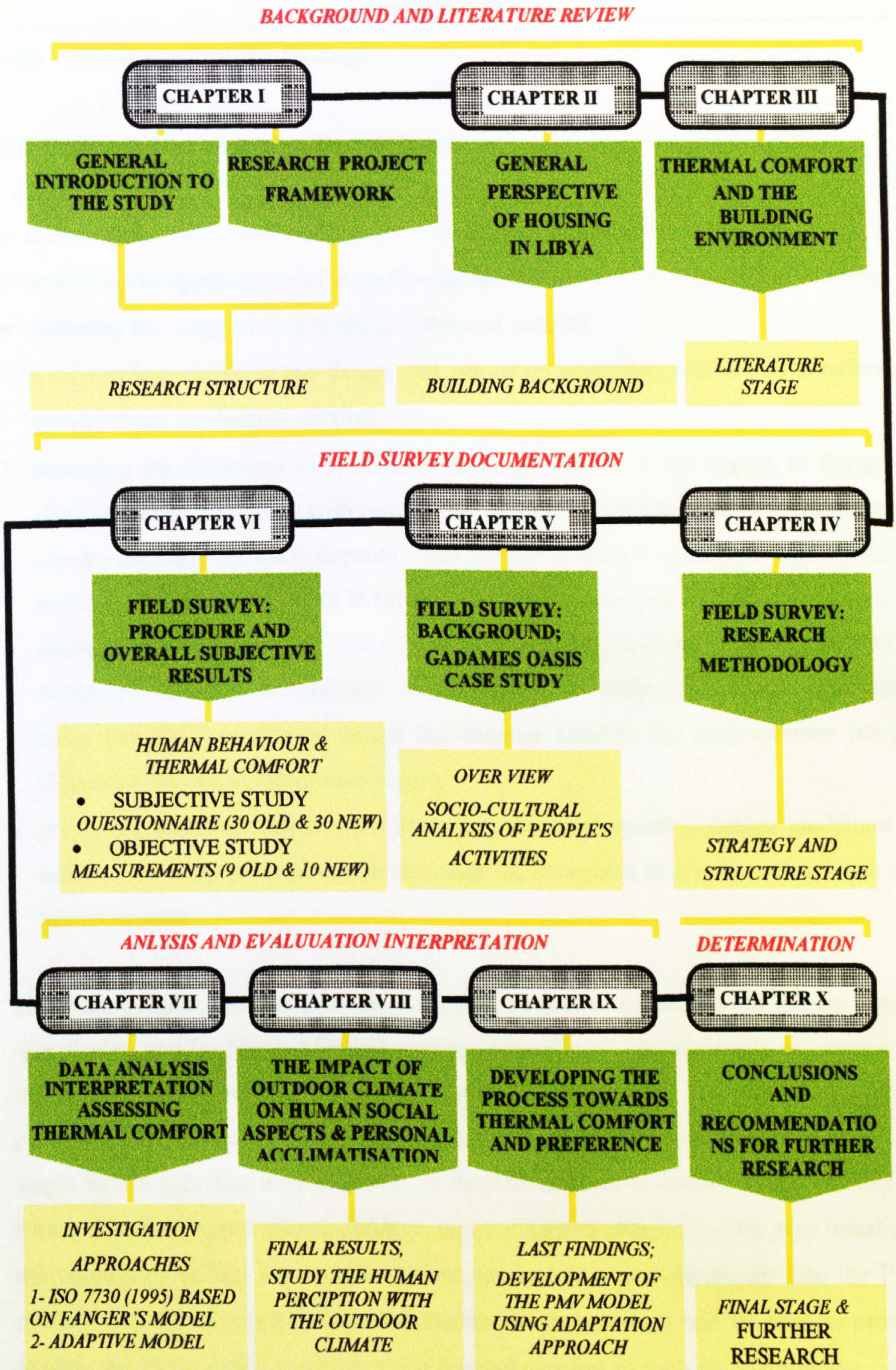


Figure 1.2:- Research Framework.

1.3.6 Significance of the findings

The findings of the research will contribute to:

- assessing the applicability of Fanger's comfort model in such environments.
- assessing the applicability of Adaptive model comfort model in such environments.
- widening the range of data relating to thermal comfort
- a refined knowledge of the design and use of an adaptable, robust and transferable questionnaire on thermal comfort.
- analysing the behaviour of traditional buildings typical to the region, in the given climatic setting especially with regard to courtyard design which can provide comfort climate naturally for the occupants. The impact of natural ventilation was identified as the most influencing factor in the design of climate-conscious architectural forms.
- assessing human social life and their personal acclimatisation, which are important factors of an adaptive approach, which should be taken into consideration when using the PMV models to assess the thermal comfort for such extreme hot-dry climate as the one in Ghadames region.
- proposing technical advice and producing the best building design guidelines to achieve an acceptable indoor environment for occupants to live in such a harsh and severe climate.

The findings from this research will eventually be part of a blueprint for Libyan regions specifically, and for North African countries generally, in terms of study or research for thermal comfort in building design. The author hopes that this research will be able to pave the way for areas to be preserved, and enhance the indoor environment at each single building in line with the spirit of thermal comfort in hot-dry climates. For the future this study hopes also to generate areas of further research on the cost benefits in the context of adding the outside air temperature as a new parameter into the PMV model. The new parameter (i.e. the outside air temperature) will be used in order to modify the PMV model to measure the thermal comfort in such an environment. Also, to what extent does this modification together with the adaptation approach, help to sustain and enhance the socio-cultural value of the buildings in question? Another field of study would to be look into the effect of this new approach upon thermal comfort. In addition, the significance of the above findings could lead to a recommendation as to how organised management is needed from UNESCO to co-operate with local building authorities in Libya. This co-operation would help ensure the survival of the traditional design of buildings that are naturally ventilated in many areas, such as Ghadames and the old towns of Tripoli and Benghazi. It will protect traditional buildings and preserve areas under the World Heritage Conservation list, so that they will not be devalued through unsympathetic development.

Chapter Two:

General Perspective of Building in Libya

"Even when the physical possibilities are numerous, the actual choices may be severely limited by the cultural matrix. ... Form is in turn modified by climatic conditions (the physical environment which makes some things impossible and encourages others and by methods of construction, materials available and the technology (the tools for achieving the desired environment)". Rapoport (1969: p47).

2.1 Introduction

Traditional Arabic building has changed in its materials, design, and function. However, the form of the Arabic traditional building and settlement structures, which have evolved naturally over a long time in response both to local climatic and topographical conditions, and the Arab people's culture and life-style, are increasingly at risk. Unfortunately, the pressures of modern development and the new materials and technologies available to the building industry together with Western ideas, reduce privacy, weaken social and family cohesion, and demean the values of the traditional Arab building (Shawesh, 1996). Thus the domestic environment which was created to satisfy family needs for social status, identity, security and domestic comfort is threatened.

In spite of this fact, many studies (i.e. Fathy, 1973; Buchanan, 1975; Bukamur, 1985; Shalaby, 1986; El-Fortia, 1989; etc.) have emphasised that contemporary housing is not able to provide the same level of comfort as traditional building. The problem now, is that many people (rich or poor) view buildings as objects of beauty as much as for protection and this has had a profound impact on construction cost, which has risen.

2.2 Climate, Building and Urban Fabric Relationship

The city and building might be one of the big problems of planning the environment and life of people today, because the planning process should provide healthy conditions and interactions in a building area and its integration with the other parts of the city. Therefore, it is very important to study the relationship between the climate, building and the urban fabric, before addressing the overview of building design in Libya and its influences. The following sub-sections will be used as bases and background for both chapters 8 and 9, in which these issues will be discussed in more detail in terms of thermal comfort.

2.2.1 Characteristics of the Urban Climate

In urban design, the main interest is in comfort and stress people experience in walking outdoors. However there is a "complex interaction and feedback ... between the building and their outdoor environments. The indoor climate and comfort in any given building depends on the climatic conditions surrounding the building. But the building itself modifies the climatic conditions on the air surrounding it. The urban geometry and profile, shape, height and size of the buildings, orientation of streets and of buildings and the nature of the urban open areas, all ... have an impact on the urban climate" (Givoni, 1989: 1-2). The terms urban canopy, which refers to the space bounded by the urban buildings up to their roofs - Givoni, (1989), and urban air dome, which is the volume of air affected by the city, the urban boundary layer - Givoni, (1989) are usually used in describing the urban climate. The following points about its characteristics may be highlighted:

1. There is a modified micro-climate in an urban area which is different from the regional synoptic climate. This is brought about by the structure of the city, (Givoni, 1989).

2. "The specific climatic conditions at any given point within the canopy are determined by the nature of the immediate surroundings" and, "the upper boundary of the urban canopy varies from one spot to another because of the variable heights of the buildings" (Givoni, 1989: 1-2).

3. Air temperatures in densely built urban areas are generally higher than temperatures in surrounding open country. This, phenomenon is known as the urban heat island effect. It is usually brought about by differences in overall net radiation balance between urban areas and surrounding open areas; storage of solar energy in the mass of the buildings; concentrated heat generation by activities taking place in the city; lower evaporation rates; and seasonal heat sources, e.g. winter heating, air conditioning, etc. (Givoni, 1989).

From this brief description of the characteristics of the urban climate, its relationship with building and the urban fabric will now be considered. It is quoted in Bennet, (1977: 5) that, "at the very moment when by our wit we have developed the means to give us control over our resistant natural environment we find we have produced in the means themselves an artificial environment of such complication that we cannot control it ...". This statement reflects the cyclical relationships between climate, building and the urban fabric. The following points together with Figure 2.1 will further describe these relationships:

1. Environmental conditions such as air temperature and radiant temperature, air velocity over the body and humidity, affect the comfort of individuals. (BRE, 1980; Givoni, 1989).

2. Different design solutions for individual buildings required to cope with each type of discomfort are affected by the climatic conditions within the urban canopy, "... which at any given place can be quite different from the conditions prevailing above in the urban air dome".

3. Individual buildings, their shape, height and size, the urban geometry and profile, orientation of streets, etc. also have an impact on the urban climate.

4. Special details of individual buildings can have significant impact on the exposure conditions and comfort of pedestrians in the streets.

5. The built form of urban areas, urban activity (transportation, industry, etc.), affect radiation, air temperatures, air velocity over the body, energy use, etc., and the comfort and health of the people living in a city. It has been observed, for example, that "... high thermal stress may lead to chronic fatigue, reduced productivity and deterioration of the public health". (Givoni, 1989: 1-13).

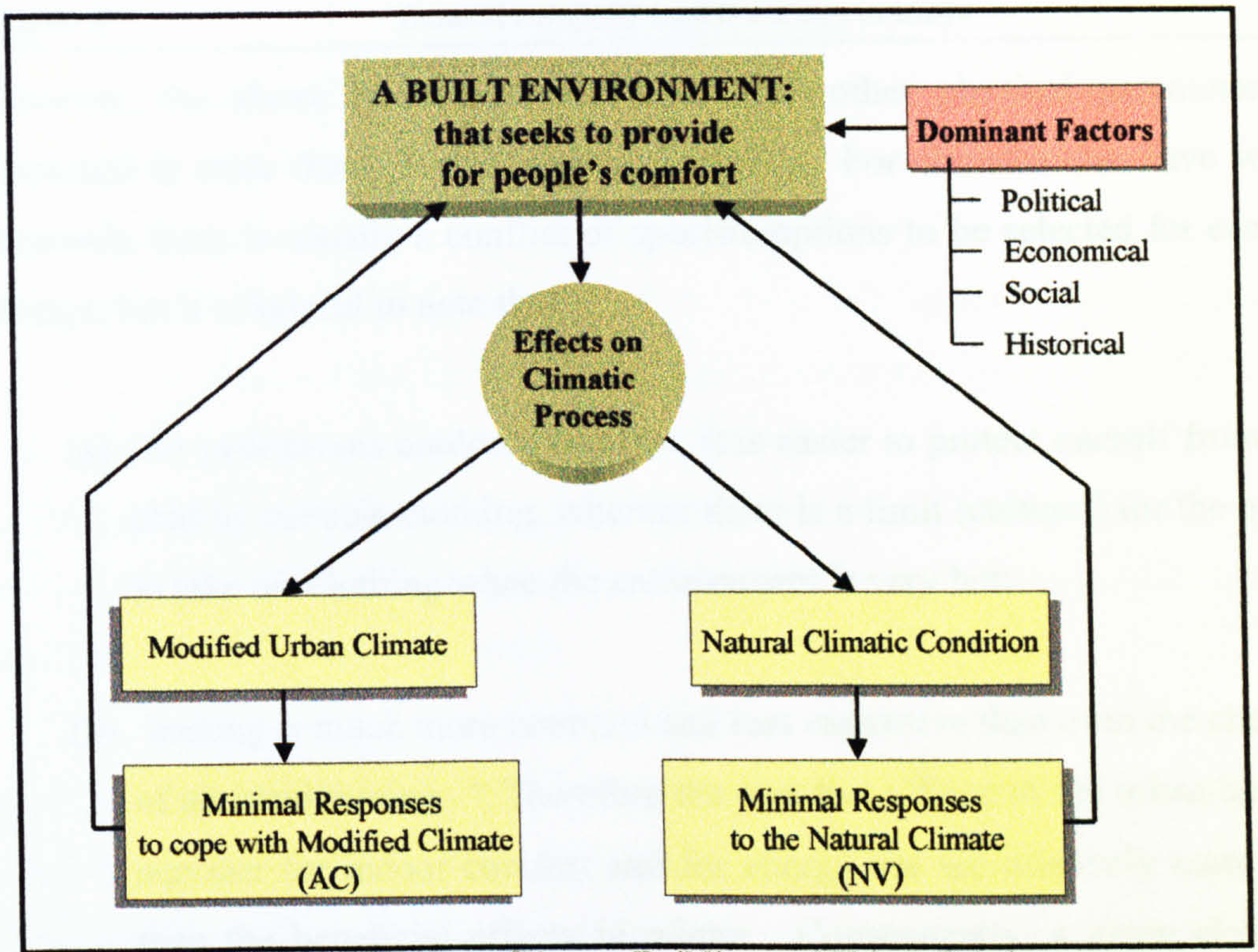


Figure 2.1: Relationships between Climate, Building and Urban Fabric.

2.2.2 Climate and Needs for Building Design

From the above description of the urban climate and its relationship with building and general built area, it is obvious that for a reasonable degree of comfort to be achieved, various design considerations with respect to a particular climate should be taken into account. This section will briefly outline some broad principles that apply to some climates. Climatic determinism has been widely accepted in architecture as well as in cultural geography, although in the latter it has recently found rather less favour. One need not deny the importance of climate to question its determining role in the creation of built form. In architecture the climatic determinist view has been stated that primitive man is concerned primarily with shelter, and consequently the imperative of climate determine form. In considering the environmental conditions, which affect human comfort, a general principle for hot climates is that:

(a) air temperature needs to be lower than the temperature of the skin in order to cool it by convection;

(b) air movement (velocity) is needed to bring air into contact with the skin and minimize the effects of humidity which impedes evaporation. (BRE, 1980).

However, the above two parameters and some other physical parameters will be discussed in more detail in the following chapter. For climates that have winters and summers, there is usually a conflict of specific options to be selected for each climatic change, but it is helpful to note that;

(a) for pedestrians outdoors comfort, it is easier to protect oneself from excessive cold by suitable clothing, whereas there is a limit (cultural) for the possibilities to take off clothing when the environment is very hot;

(b) heating is much more common and less expensive than even the cheapest form of air conditioning. " Therefore the negative effects of the urban heat island in summer for indoor comfort and for energy use are relatively more significant than the beneficial effects in winter. Consequently, a given element of the urban temperature in summer has a greater harmful effect on human comfort and health than the beneficial effects on a similar elevation of the temperature in winter." Givoni, (1989: 2-7). It is therefore a general principle to adopt the design considerations specified in Table 2.1.

Table 2.1: Design considerations for some climates.

TYPE OF CLIMATE	DESIGN CONSIDERATION
Cold winters and comfortable summers	It is desirable to elevate the urban temperature; minimize wind speed in the urban space, mainly near the ground; maximize the exposure of buildings and streets to the sun.
Hot summers and comfortable winters	Lower urban temperature as much as possible (or at least minimize the usual elevation of the urban temperature above the regional level); provide shade for pedestrians on the sidewalks; if summers are hot-wet, increase the wind speed in the streets.
Cold winters and hot summers (either hot-dry or hot-humid).	For winter: minimize wind speed; maximize solar exposure. For Summer: maximize wind speeds; minimize solar exposure. This obviously could be quite difficult but design principle mentioned above should be considered.

Source: Compiled from Givoni, (1989: 1-5).

The development of the Libya and the rapid growth of population have created high density and built-up areas all over the country. Obviously, this development is to be promoted as an integral component in economical and social development, and is fundamental in the transformation of a decaying urban fabric. This building development has an effect on health. Increased heat generation within the urban fabric may affect the general public health. However, pollution in the urban areas is intensified by increased activities in the built environment (i.e. water, sewerage, traffic, etc.), and this can cause recurrent colds/ throat infections and aggravate existing sinus or asthmatic problems (Givoni, 1989).

With the increased urban temperature due to the structure of the built form, it could be expected that more energy is consumed in electricity for as such air conditioning, which will affect the supply of electricity. In other words, it could be the result of increased demand for energy. The demand for energy is constantly growing all over the world and is fuelled by the world's escalating population. The destructive consequences of industry on the environment are in many cases already evident (especially in the Industrial Countries), in others controversial. Examples include the 'Chloro-flouro carbons' which are used in refrigerators, which are destroying the layer of 'Ozone' in the outer atmosphere which protect the earth from the sun's ultraviolet rays; also, 'Greenhouse gases', which affect the earth's surface temperature, causing it to use. Further more, road vehicles and responsible for emitting a fifth of the thropogenic carbon dioxide in air.

In general, World Health Organization (WHO) promotes the healthy city that there is a very strong relationship between the ecological setting; cultural setting; climate and economy; public participation; and infrastructure.

2.3 Overview of Libya

2.3.1 Location and Demographic Background

Libya is an Arabic Islamic Country, located on the central Mediterranean coast of North Africa between Egypt and Tunisia. It is the fourth largest country in Africa, as large as France, Italy, Spain, and the former-West Germany combined, having total area of 1,780,000 sq. Km (680,000 sq. mile), see Figure 2.2. However, 91 per cent of its area can be considered harsh or uninhabitable, consisting mainly of desert, which affects population distribution. As a result, just 10 per cent of the country is occupied by nearly 90 per cent of the population, the bulk of which live within 10 kilometres of the coast. According to UN estimates, Libya recorded the fastest population growth among the North African countries in the Middle East between 1970 and 1974, (4.2 per cent).

From a historical background, the Greeks gave the name Libya to all of northern African regions. It was one of the regions of the Islamic nations, and as such did not appear on the maps of colonial Africa (Villard. Henry Serrano, 1956). In 1911, Italian colonialists unified the area under their control. Modern Libya as a country, came into being after World War II, as a result of a United Nations decision in November 1949. Libya became a Kingdom in 1952, after gaining independence from Italy. In September 1969, the new revolutionary regime came to power, and name of Libya changed to the Libyan Arab Republic. In 1977 Libya was adopted as the shortened name for its recent formal name 'The Socialist Peoples Libyan Arab Jamahiria' (SPLAJ).

After 1951, when Libya regained its autonomy as a self governing Kingdom, family size had increased, people married younger, and the death rate declined, resulting in rapid population growth (see Figure 2.3). The total population of Libya in 1954 was 1,089,000. In 1964 this had grown to 1,564,000 (an increase of 43.7%) and by 1973 it was 2,251,000 (an increase of a further 46.5%).

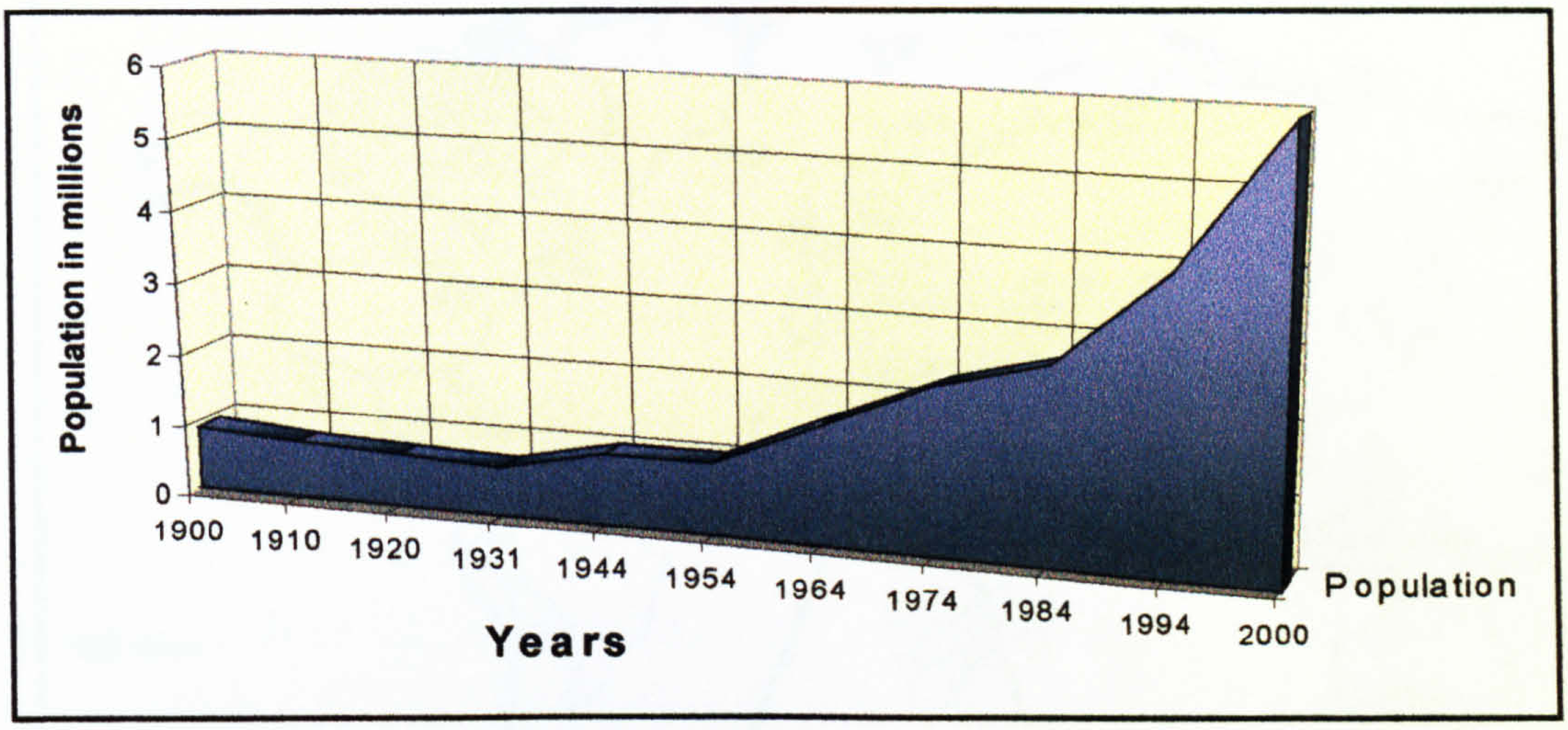


Figure 2.3: Population Growth in Libya, 1910-2000*. Source: Ministry of Planning 1989. (*Perfected Population estimates for year 2000).

The population grew by an average of 4% between 1980-2000, before decreasing by around 3% at the end of this period. Therefore, 3.5 % has been considered as an average growth rate over the whole period. Ministry of Planning (1989: 19-20). Immigrants are attracted by the industrial and construction development of the country, giving rise to the prospects of employment acting as a magnet to workers in neighbouring countries who settle in the major towns.

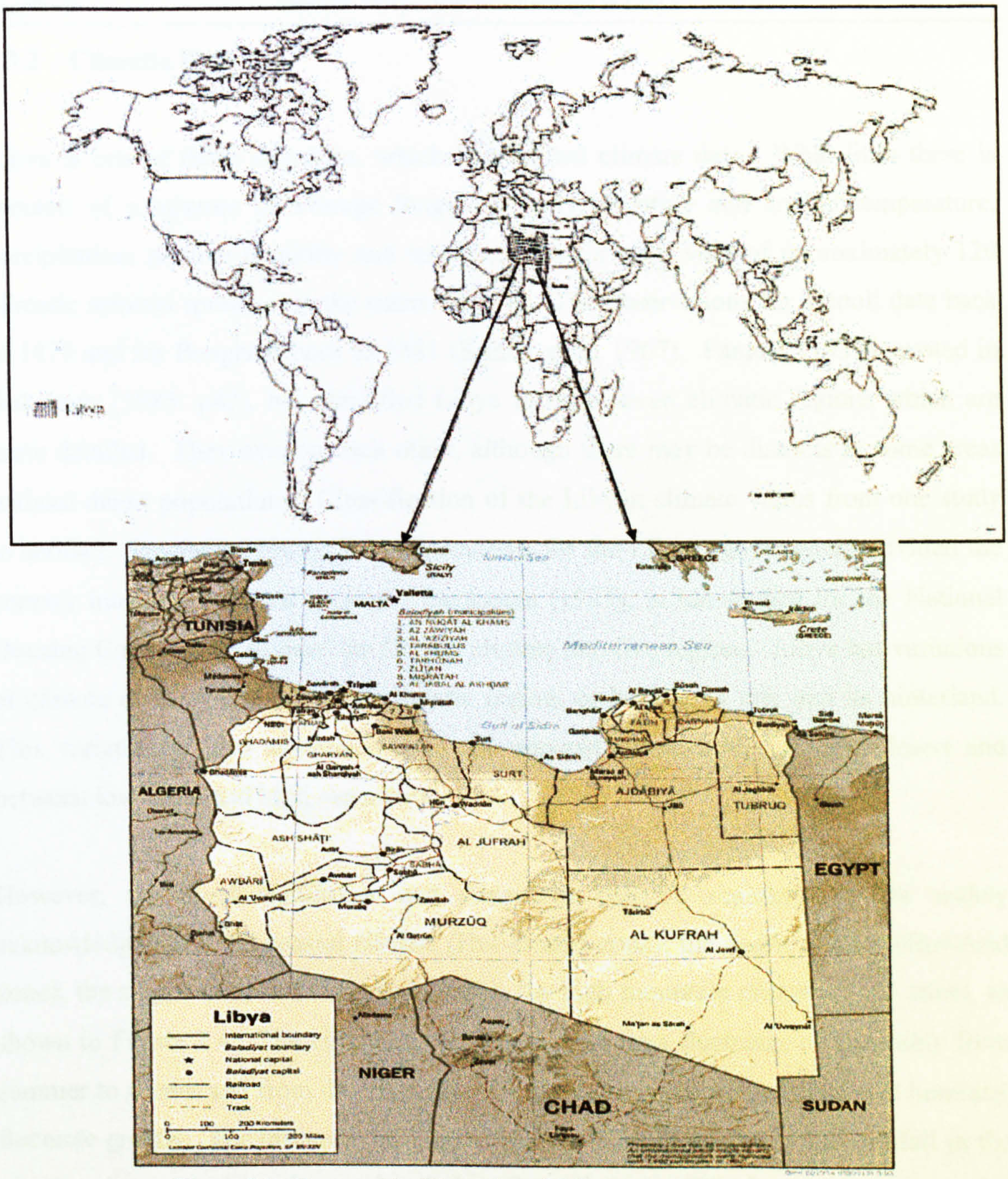


Figure 2.2: Geographical Location of Libya.

2.3.2 Climatic Data

Libya is one of those countries, which has limited climate data. What little there is consists of a mixture of average long-term daily, monthly and annual temperature, precipitation, relative humidity and sunshine data for a network of approximately 120 climatic stations spread over the entire country. The observations for Tripoli date back to 1879 and for Benghazi back to 1881 (Kanter et al, 1967). Fantoli, (1937), quoted in Bukamur, (1985: p42), has classified Libya to have seven climatic regions which are more detailed. They overlap each other, although there may be districts in some areas without dense populations. Classification of the Libyan climate varies from one study to another. Doxiadis (1964), in his documents for the Libyan government, divided the country into three climate regions. Buchanan (1975), in his studies for the National Housing Corporation, divided the Libyan climate into five regions. Libya has variations of climate even within the same climatic region, or between a city and its hinterland. This variation is also associated with the contrast between the sea and desert and between low areas and high mountains.

However, the most significant and consistent climatic regions that are widely acknowledged are: the coastal climate (Hot-Humid zone); the desert climate (Hot-Arid zone); the steppe climate (Temperate zone); the high mountain climate (Cold zone), as shown in Figure 2.4. The climate of all regions in Libya fluctuates considerably from summer to winter and from day to night. Wind storms, temperature, rain, and humidity fluctuate greatly. For instance, Tripoli, which has the highest amount of rainfall in the country, has experienced occasional droughts of up to 220 days, as was recorded between April and November 1928. Another extreme weather fluctuation was recorded at the Azizia weather station, (40 Km south of Tripoli) which reported the highest shade temperature ever recorded in the world, 58°C, on September 13, 1922. (McWhirter et al, 1983).

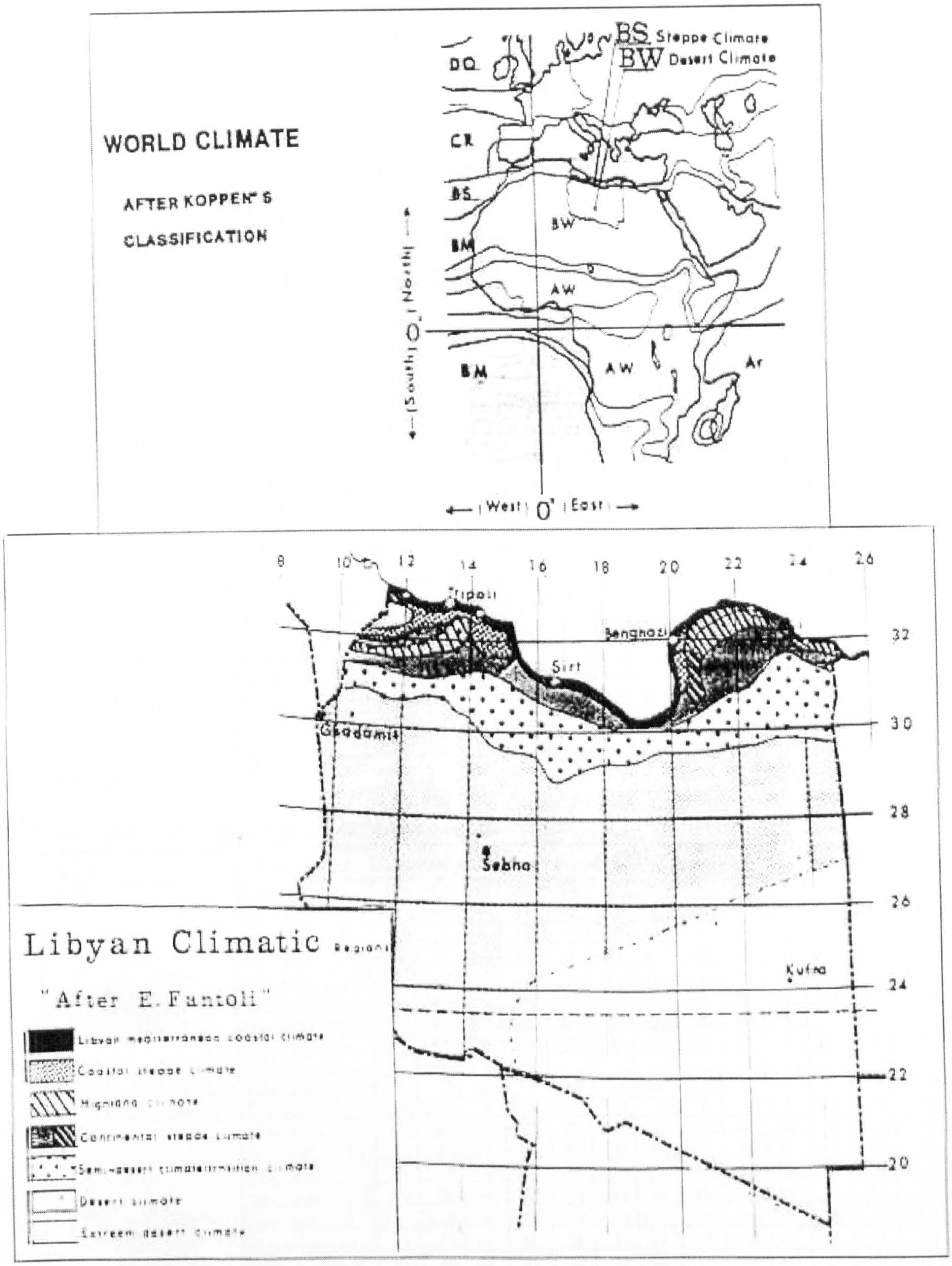


Figure 2.4: The general classification of the Libyan climate, and its climatic regions. Source: Kanter, (1967), and Buxtehude, (1981) Quoted in Bukamur, (1985: 43-44).

This desert region has also reported a variation of more than 30°C between day and night on many occasions. Tables (2.2a & 2.2b) present some important climatic data from seventeen major weather stations. The General People's Committee of Transportation in Tripoli measures and gathers Libyan climatic data for use in architectural and general design. They do not provide guidelines on how the data may be interpreted during the process of design.

Table 2.2a: Climatic Data of Libya (Hoon and Gialo).

Station	Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
HOON	Temp °C Daily Ave	11	13	16	21	24	28	29	28	27	21	17	12	20
	Temp °C Ave Max	19	22	25	26	34	37	38	38	37	24	25	20	24
	Temp °C Ave. Min.	3	4	7	10	14	18	18	19	17	13	8	4	12
	Temp °C Abs. Max	30	37	40	42	45	46	47	46	45	41	35	32	47
	Temp °C Abs. Min.	-6	-5	-4	2	6	10	12	10	10	4	-1	-6	-7
	Diurnal range Temp	16	18	18	16	20	19	20	19	20	16	17	16	17
	Relative Humidity %	58	52	46	41	37	34	40	41	44	55	57	56	47
	Evaporation cm.	11	14	18	20	27	28	33	29	22	18	12	10	24
	Sunshine hours													
Elevation 260 m.	Vapour press mbs	7	7.5	8	9	10	12	19	15	14	13	10	7	12
ft.	Rain fall mm	2	1	1	0	0	0	0	1	5	9	3	2	33
GIALO	Temp °C Daily Ave	13	15	17	22	26	29	29	29	27	24	19	15	22
	Temp °C Ave. max.	20	22	26	30	34	39	37	36	34	31	26	21	30
	Temp °C Ave. min.	6	7	10	14	18	21	22	22	21	16	11	8	15
	Temp °C Abs. max.	30	35	43	44	49	48	47	47	44	41	39	32	49
	Temp °C Abs. min.	-2	1	2	6	9	13	17	16	14	8	3	0	-2
	Diurnal range Temp	14	15	16	16	16	18	15	14	13	15	15	13	15
	Relative Hum %	57	52	47	40	35	34	35	40	45	50	55	58	46
	Evaporation cm.	10	12	18	21	28	32	34	26	29	16	12	11	246
	Sunshine hours													
Elevation 61 m	Vapour press mbs	8	9	10	11	12	15	15	17	17	14	12	9	12
ft.	Rain fall mm	1.4	1	0.6	0.5	0	0	0	0	0	1	2	2	10

Source: Bukamur, (1985, p. 245).

Table 2.2b: Climatic Data of Libya (Kufra and Ben-Wlid).

Station	Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
KUFRA	Temp. °C Daily Ave.	13	16	19	23	29	32	33	31	29	25	18	14	23
	Temp. °C Ave. Max	26	29	34	41	42	46	45	43	39	38	33	27	45
	Temp. °C Ave. Min	5	6	10	15	19	22	22	23	19	16	9	6	15
	Temp. °C Abs. Max	52	37	41	44	45	46	48	44	42	41	37	33	46
	Temp. °C Abs. Min	-2	-1	1	2	9	16	17	13	3	2	-1	-2	-2
	Diurnal range Temp	21	23	24	26	23	24	23	20	20	22	24	21	20
	Relative Humidity %	47	39	33	28	26	25	26	26	30	34	43	45	34
	Evaporation cm	13	15	20	24	28	33	35	32	24	19	15	13	271
	Sunshine hours													
Elevation 389 m.	Vapour press mbs	7	7	8	9	10	11	13	13	12	11	10	7	10
1276 ft.	Rain fall mm	0	0.4	0	0.5	0.2	0	0	0	0	0.1	0.1	0	2
BEN WLID	Temp. °C Daily Ave.	12	14	17	20	24	28	30	39	27	23	18	13	21
	Temp. °C Ave. max	17	20	23	28	32	38	39	38	36	31	25	19	29
	Temp. °C Ave. min	6	7	9	12	16	19	21	21	18	14	11	6	14
	Temp. °C Abs. max	30	35	36	42	45	46	48	48	46	41	39	37	48
	Temp. °C Abs. min	0.1	0.5	1	4	7	9	13	14	10	6	3	-1	-0.5
	Diurnal range Temp	11	13	14	16	16	19	18	17	18	17	14	13	15
	Relative Hum %	52	49	48	43	39	38	38	39	43	46	47	49	44
	Evaporation cm													
	Sunshine hours													
Elevation m.	Vapour press mbs													
- ft	Rain fall mm													

Source: Bukamur, (1985, p246).

2.3.3 The Principal Influences that Impact on Building Design in Libya

2.3.3.1 Building Development, Political and Economical Changes

Government prior to 1950 had not addressed the building problem in Libya, and the country suffered from a shortage of housing in both urban and rural regions. There were no permanent or continuous building census programs. The private sector as a potential source of building for either rent or sale was also completely ignored by the government decision-makers.

The first influence on building in Libya was the granting of independence in 1951, followed by the discovery of oil in 1953. These have led to significant changes and developments, e.g. population growth; improvement in health care; new government policies and infrastructure concerning roads, communications, finance, land and income of the people. These changes, in addition to the rural-urban migration put pressure on urban infrastructure. The degree of urgency and pressure experienced by the building authorities increased, given the efforts aimed at meeting building demand. This was particularly the case after the change in regime brought about by the Revolution of September 1969. As a consequence of this pressure, the government sought help from Western and Eastern countries. They were instrumental in the provision of a large number of units to house as many people as possible in a short period of time, resulting in the devotion of huge government expenditure to the housing sector. Addressing building problems was one of the most important goals of the new government, who viewed this as a major task in the reshaping of the nation. Perception of quality was very basic, and the main aim of foreign companies was to gain lucrative contracts. Allan, (1981) stated that in that year 365,000 households were living in 300,000 habitable dwelling units, leaving a deficit of 65,000 dwelling units.

However, the Revolutionary Government was not only strongly committed to rapid growth of the housing sectors, but also stated that the allocation of the building units was more equitable than in the past. The volume of expenditure allocated to building expanded substantially from Libyan Dinars, LD 32.8 million in 1970 to LD 185 million in 1977 to LD 794.2 million in the period 1976-1980. (Awotona, 1990).

The discovery of oil in Libya created an improved economic situation, annual income from oil growing from around one billion dollars before the Revolution, to more than two billion dollars. This stimulated population growth, migration to the major cities from rural areas, and immigration from the neighbouring states of Tunisia, Egypt, etc. As a result, since the 1980s housing need has overtaken supply. In an attempt to deal with the problem politicians gave power to local authorities and engineers allowing them to deal directly with all levels or groups of citizens in order to determine their exact needs.

Providing homes and work for this increase in population presents a substantial problem. Awotona (1990) stated that the most serious impediments to providing housing included the following: quantitative housing difficulties: a substantial stock of substandard dwellings; poor maintenance of existing stock which were in reasonably good condition; lack of, and inadequate distribution of, community buildings and facilities; the proliferation of slums; unplanned development of cities, town and villages; high cost of urban land; severe shortage of technical and skilled labour for the construction industry; shortage and high cost of building materials; the high rate of population growth; massive urban-ward migration; and the special housing needs of nomads who constitute about 21% of the total population.

2.3.3.2 Social and Cultural Influence

So many architects such as Fathy (1973), El-Barbour (1989), El-Fortia (1989), and recently Shawesh (1996) mentioned that the people who have been looking for an image of modern life. They and have lavished their money on fittings and decorations in urban housing, have denied themselves suitable living spaces, which could have been created using both their real craftsmanship and traditional materials. They have built their buildings to display their increased affluence, working against nature instead of with it and thus undermining the basis of their existence and that of future generations. These new forms of buildings for both rich and poor alike ignore the Arabic vernacular architecture. For example courtyards, very typical Arabic forms, are perceived as old fashioned and are therefore unpopular, and their benefits are ignored.

New building units have been constructed without any attention to cultural factors. Rapoport, (1969) argued that the house is an institution, not just a structure, created for a complex set of purposes. Because building a house is a cultural phenomenon its form and organisation are greatly influenced by the cultural milieu to which it belongs. Therefore, he argued that the physical form of the built environment results from people's behaviour patterns in society. Such a view would mean that such patterns could dictate the shape of housing, allocation of space, orientation of buildings and form.

Religion can affect the plan, form and orientation of a house as an even more significant factor for unity. For instance, in Libya the people take a pride in their brotherhood of Islam. One of the main issues is *'privacy'*; from public (street) to semi-public to private (house). El-Fortea, (1989) stated that privacy is a fundamental need for both religious and cultural reasons. Based upon that, segregation between sexes, and privacy between them, is one of the most essential characteristics of Islamic society, and these considerations can clearly be seen in the design of traditional buildings in Libya. A building is designed in such a way that a visitor, on entry, has to pass a door keeper, then through an angle in an entrance passage thus preventing any one outside from seeing into the building, (Nour, 1979). See Figure 2.5. The windows are planned so as not to overlook any other building, and neighbours cannot see the residents inside the courtyard. In planning public spaces such as markets and the private space of the courtyard, each part of the circulation network achieves some kind of privacy, as shown in Figure 2.5.

Modern buildings in Libya are predominantly of two types; normal dwellings which are entirely constructed on site and mainly in concrete by the private sector; and prefabricated flats which consist of pre-cast units constructed in factories and are built by the public sector. Unfortunately, the building authorities construct these units without any attention to cultural factors, using designs, which require the sharing of entrance and corridors. For these reasons, modern flats are unpopular with local families, who often make substantial alterations inside their flats. Recently, many studies on modern housing in Libya (i.e. Buchanan, 1975; Essayed, 1981; El-Barbour, M., 1989; and Allan et al, 1989) have highlighted the psychological and social problems caused by the poor and weak quality of the built environment. All of these issues will be used to address the human perception of thermal comfort, see chapter 8 for more details.

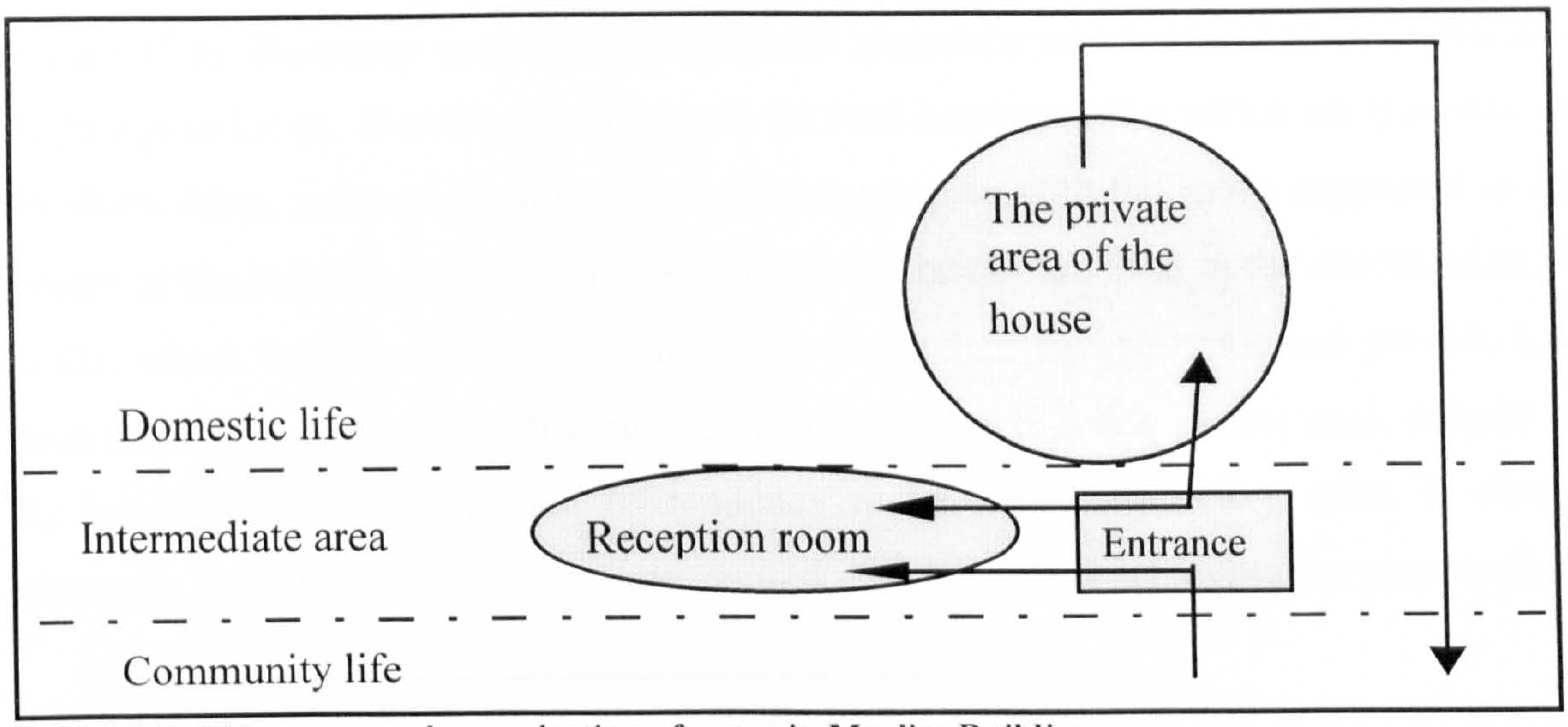


Figure 2.5: The conceptual organisation of space in Muslim Building.
Source: Shalaby, T., (1986).

2.3.3.3 Climate and Building Materials

A person can change his/her living environment and be changed by it. Thus, the environment can affect a building. In North Africa, roofs are flat, and are sometimes used for sleeping, while in Northern Europe, where there is snow and rain, buildings usually have gable roofs. In the humid tropical regions they build their huts of grass and reeds, just to get air through the walls, as well as using a steeply pitched roof.

Anecdotal observation has shown that by ignoring traditional materials and moving toward modern materials, there has been a negative impact on the cost and comfort of buildings. "It is obvious in a hot dry climate such as exists in Libya with long hot summers and cold winters, that new buildings could not achieve as much comfort as traditional buildings" Shawesh, (1995). Furthermore, he mentions that the traditional buildings in hot dry climates perform well thermally and provide the necessary comfort for occupants. This is mainly because of the thermal storage capacity of walls and roofs associated with small openings. People use natural materials for their traditional buildings that have proved their capability and durability, as many historical buildings built long ago are still surviving. In Libya, all of the traditional materials (i.e. clay soils, stones, mud and sun-dried bricks, palm, palm fronds and trunks, etc.) are widely available throughout the country.

Figure (2.6) illustrates some of these natural materials which are used in traditional buildings in Libya. Burnt bricks are used, for load bearing-walls, which are typically 40 to 60 cm thick, and the buildings are rectangular in plan with flat roofs, supported in the centre of the building by brick pillars. Burnt clay bricks are used in the construction of walls, which were favoured for their ability to insulate against noise and provide low heat transfer, thus providing thermal comfort inside the building. Also, mud, in spite of its low structural strength and its tendency to be eroded by heavy rains, is cheap, generally available, and requires only semi-skilled labour for achieving the construction.

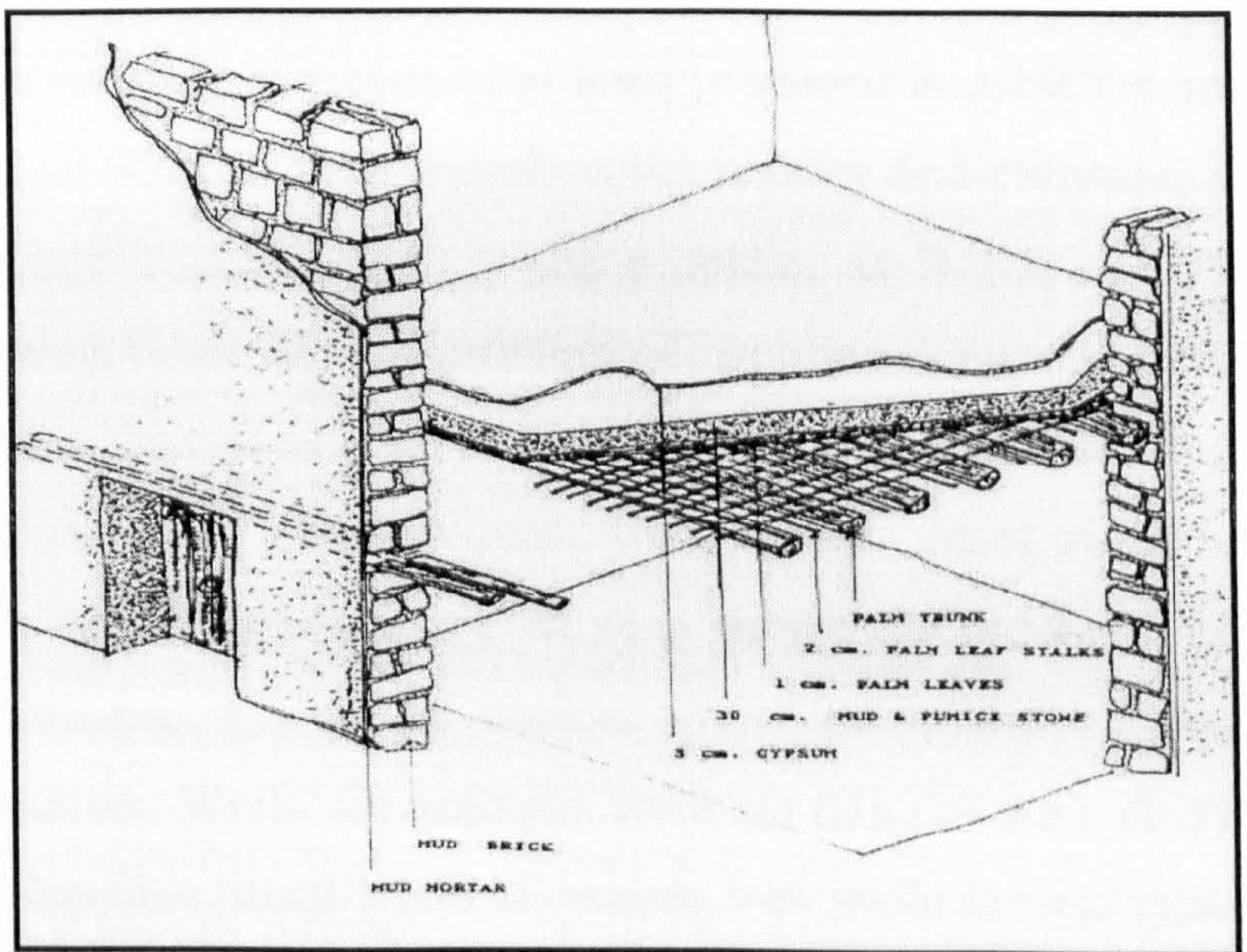


Figure 2.6: Traditional Building Materials.
Source: Shawesh, (1992).

Recently, Shawesh (1996) mentioned that due to the rapid physical development in Libya since the 1970s, vast quantities of new building materials have been made available, the majority being imported from abroad. Modern buildings constructed using these materials, in contrast, have raised a number of complaints of discomfort in summer because of overheating and coldness in winter. These problems not only result from the use of modern building materials, but are also due to western design influence and financial considerations.

People now, particularly in the arid desert area of Libya, are suffering from uncomfortable indoor environments. However, various approaches have been attempted to minimise the effect of modern materials upon human comfort. Most have proven unsatisfactory from an economic point of view, and hence average households cannot afford to apply these solutions. Modern materials require expertise and sophisticated quality control. Evans (1980) stated that a number of the new materials that have been introduced are superior to the traditional ones in many different ways. However, they have been introduced with little thought of how they might best be used, especially in many tropical developing countries where no practical experiments and research have been carried out to determine their suitability to the climatic conditions. Their use has had undesirable economic side effects in many developing countries where imported materials and technology contribute greatly to balance of payments problem.

Modern building materials have been produced in great volume in Libya by the public sector (i.e. steel and steel framework, sanitary and electrical fittings, plastic materials, lightweight concrete, etc.). The problem, as Bessey, (1975) has stated, is that in developing countries, the problem of avoiding defects is frequently even greater than elsewhere since there may be less experience of some building techniques, particularly when these have been introduced from abroad. Most of the housing projects in Libya built in the 1960-90 era, are showing substantial problems; of cracks, settlement, and even collapse. Climatic factors were not given emphasis or attention during construction. Walls, for example, were too thin (20 cm.); roofs were not protected from direct sunshine, insufficient allowance was made for the expansion and contraction of joints. In addition, the use of concrete and steel involved in the construction of housing has caused problems. However, to achieve good curing of fresh concrete blocks they have to be protected from direct sun light. This, unfortunately, is not common in Libya. For instance, during the hot summers, the high ambient air temperature and intense sun radiation make it difficult to control the water content of concrete mixes. Stock piles of aggregates and cement becomes heated during the day, as do all metal parts. This includes the mixing drum, transport skips, form-work and reinforcing steel. Also, it requires good control of the required water. This results in weakness in the strength of the blocks. Bukamur (1985) was observed that 5% of the concrete blocks, which are commonly used in walls in Libya nowadays, are broken during loading. Even the pre-cast modern flats which have been constructed by the public sector, for example in Benghazi (Eastern part) and Tripoli (Western part), using modern materials present climate related problems. High indoor temperature means that most of these flats require the provision of air conditioning to achieve thermal comfort, resulting in high overheads in electricity costs.

2.4 Aspects of the Arab Courtyard Building

2.4.1. Its Genesis and Definition

The courtyard house has been described by Fathy (1973) and Al-Azzwi, (1986) as 'Bayt Maftooh' (an Open House), or as 'Bayt Sharqi' (an Oriental House), or 'Bayt Qadeem' (an Old House). They have come about as a result of the introduction of non-courtyard houses in Libya, which are known as 'Bayt Gharpi' (an Occidental or Western house), or as 'Bayt Oroppi' (a European house), or as 'Bayt Hadeeth' (a New or Modern house). These euphemisms are diametrically opposed and denote the characteristics of both types of buildings. The courtyard is the main element in traditional houses. It refers to an internal, enclosed space open to the sky with habitable spaces and rooms and ancillary areas grouped around it (on two, three or four sides and on one or two storeys) which look inwards for daylight and natural ventilation. It is used as an open air family 'living' room in spring, summer and autumn, but particularly so in summer when almost all family activities take place there or spread into it. The courtyard is commonly referred to as 'Wast Housh' (a Middle House), which literally means the space at the middle of the house normally surrounded by rooms grouped around it and overlooking it. It is also known as 'Fina' or 'Sahn' al- Dar (the open centre space of the house). Schoenauer, (1981), has stated that, the concept of organising the house around an open space was established more than 6000 years ago. The genesis of this concept might have evolved from a gradual response to a change in spatial needs of ancient-dwellers and the need for more space as the dweller's family grows.

2.4.2 Social Aspects

In fact, all the Arabic traditional houses (in Iraq, KSA, Egypt, Algeria, Libya, etc.) are built around an open courtyard. An overriding consideration in the design of such houses was the socio-religious need for privacy which coincided with the concomitant need for introverted plan form in response to the hot, dry climate. This preoccupation with the interior resulted in a conscious neglect of external elevation treatment and in almost total concentration on architectural details on the courtyard elevations (Fathi, 1973, and Roaf, 1986). The courtyard is the most commonly used living space in a traditional Arab building and is generally arrived at via a bent axis entrance from the street to avoid direct vision by passers-by to the heart of the building. This kind of courtyard ranges commonly in size from 4m x 4m to 12m x 12m. Sometimes, there are two courtyards in big houses: a small one that is an inner family court, which is essentially the domain of the ladies of the household; and a larger one that is an outer court where the men of the household entertain, which can be reached directly from the street by routes away from the ladies' quarters. The best examples of this type of building designs are to be found in Ghadames oasis in Libya. See chapter 5.

Modern buildings or villas, which are surrounded by an eye-level wall and where the courtyard is replaced by a garden, do not give the equivalent degree of privacy to their residents. This often leads to social tension between neighbours who are able to sit on their first floor balcony and overlook the garden. This means that the garden can be used only in the late afternoon. Therefore, for both climatic and social reasons, all activities must take place indoors. This requires the thermal comfort in these buildings to be enhanced to the right level in the use of air-conditioning.

2.4.3 Environmental Aspects

Environmental conditions (i.e. solar radiation, wind, nocturnal radiation, and air temperature), as well as heat exchange with adjacent building zones are affected by the heat balance of the courtyard envelope, but to a lesser degree than on the external building envelope. For instance, air temperature inside the courtyard is different from outside, as a result of the heat either being absorbed from or released to the air by the building materials. Therefore the amount of mass and its distribution, together with proper insulation, play a role in the thermal performance of the courtyard. Also, when the wind blows over a courtyard, the circulation of air and its velocity within the court will be lower than the mainstream wind, to a degree that is dependent on the courtyard geometry.

Hence, the advantage gained by reduction in outside wind velocity varies depending upon the geometry and orientation of the courtyard. High ventilation rates are not desirable during the daytime in hot-arid countries, as they lead to heating of the courtyard. However, during night-time, the temperature in the courtyard is higher than the outside night-time air, as a result of the thermal energy stored in the massive wall construction; at this time ventilation through the courtyard is desirable in order to progressively cool the mass. In addition, ventilating adjacent zones through openings (i.e. windows) will also cool the building by removing heat from the spaces.

Since openings such as doors and windows are located on the courtyard walls, overheating problems can occur in rooms if direct sunlight is able to penetrate through them. To prevent this, shading these openings is necessary, in addition to the proper selection of their size and location in certain situations. Shawesh (1995) has been stated that it is beneficial in old Ghadames town to have traditional buildings densely clustered together, resulting in a minimum amount of solar exposure on internal and external walls: "... striking impression of the townscape is produced by the chorus colour (which looks like the earth of the alleys), the whitewashed mud walls and the covered passage ways. .... The buildings are compactly built together with winding lanes and alleys passing underneath". Pedestrian networks in each district or zone provide narrow and shady streets cooled by induced air currents due to the vertical street sections, which encourage air pressure differentials. In summer, therefore, while the centre of the courtyard building has a constantly fluctuating climate, the nature of the materials from which the building is constructed helps to maintain steady conditions in the rooms around the court. The summer period can be passed comfortably by a gentle migration of cool air around the building without the assistance of mechanical cooling or heating devices.

Thus, the main critical issue, is the orientation of the building, and the major migration of the year that the inhabitants make in October from the north-facing summer quarters of the house, around to the south-facing rooms of the courtyard. In April and May they move back into the summer areas of the court and sometimes they use also the roof. In winter, entertaining and sleeping takes place in one or two winter rooms of the house due to the dramatic change between day and night time climates. A rather distinctive form of migration vertically through the building achieves comfortable living conditions. The occupants having to slep on the roof, will rise between 4:30-6:30 a.m. when the sun rises, then having had a light breakfast, those who are working or studying will leave the house at 7:00-7:30 a.m. They will arrive back home 1:00 to 2:30 p.m. The critical and the hottest time of the day in the summer is between 1 and 5 p.m., which is usually the time for eating, talking and sleeping. This can be illustrated by outlining the daily routine. More details of these human adaptation approaches will be highlighted in chapter 8.

2.4.4. Thermal Cycles in the Courtyard Building

Al-Jared, (1991) observed that the courtyard building undergoes two different thermal cycles, a 'diurnal cycle' in which most of the heat is absorbed; and a 'nocturnal cycle' in which most of the absorbed heat is released. In the diurnal cycle shown in Figure (2.7), he accounted the level of in-radiance, which changes significantly from hour to hour, due to the movement of the sun during the day and depending on the courtyard geometry. Due to low solar altitudes in the morning when the sun starts rising, almost all of the courtyard walls and the floor are usually shaded from direct solar radiation. At this time, the courtyard is exposed mainly to diffused sky vault radiation. As the solar altitude increases and approaches solar noon, more areas become exposed to direct sunshine, and the temperature of the courtyard surfaces rises rapidly as the surfaces are exposed to the solar radiation. The rate of increase depends on the angle of incidence, the convection rate and the optical and thermal properties of the surface and bulk material. Al-Jared demonstrated that the heat absorbed during the daytime is stored in the high mass materials of the traditional courtyard wall, and conducted to the other side with a delay by which time the sun has gone.

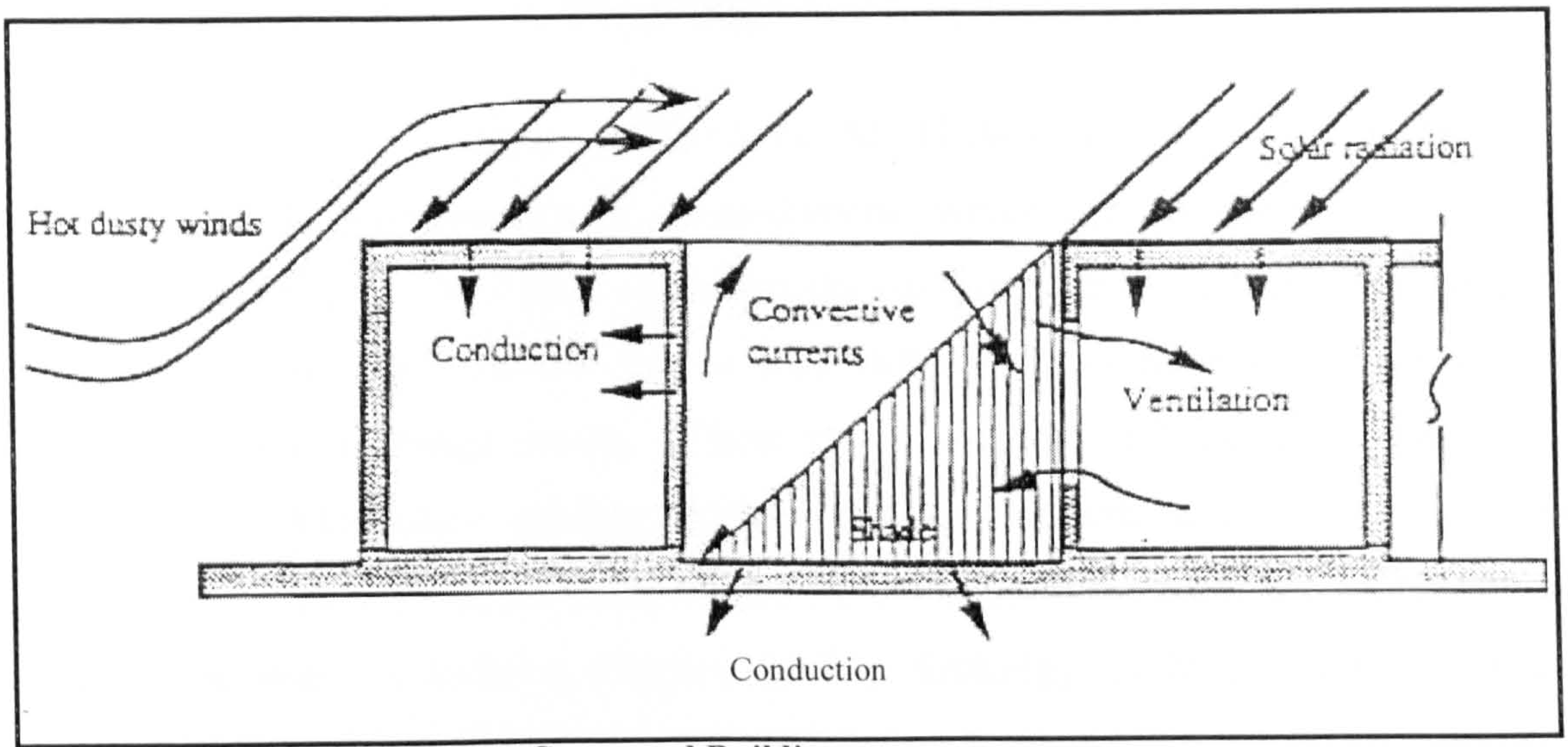


Figure 2.7: Diurnal Cycle in the Courtyard Building.
Source: Al-Jared, M., (1991).

With the onset of evening, the heat stored in the walls is released, partly into adjacent zones and partly to the court, giving rise to convector currents and a rise in the temperature of internal surfaces as shown in Figure (2.8). Thermally induced ventilation occurs and cools the walls. Loss of thermal energy increases by the increased air movement when there is a wind blowing. Accordingly, the mass cooling rate increases, and open windows facilitate the ventilation and cooling process of the rooms. In addition, the cooling rate of the mass is increased by radiation from the courtyard walls to the night sky. Once the mass has cooled down it remains cool until late morning, the lower air and mean radiant temperature enhancing the comfort of adjacent zones. Al-Jared, (1991).

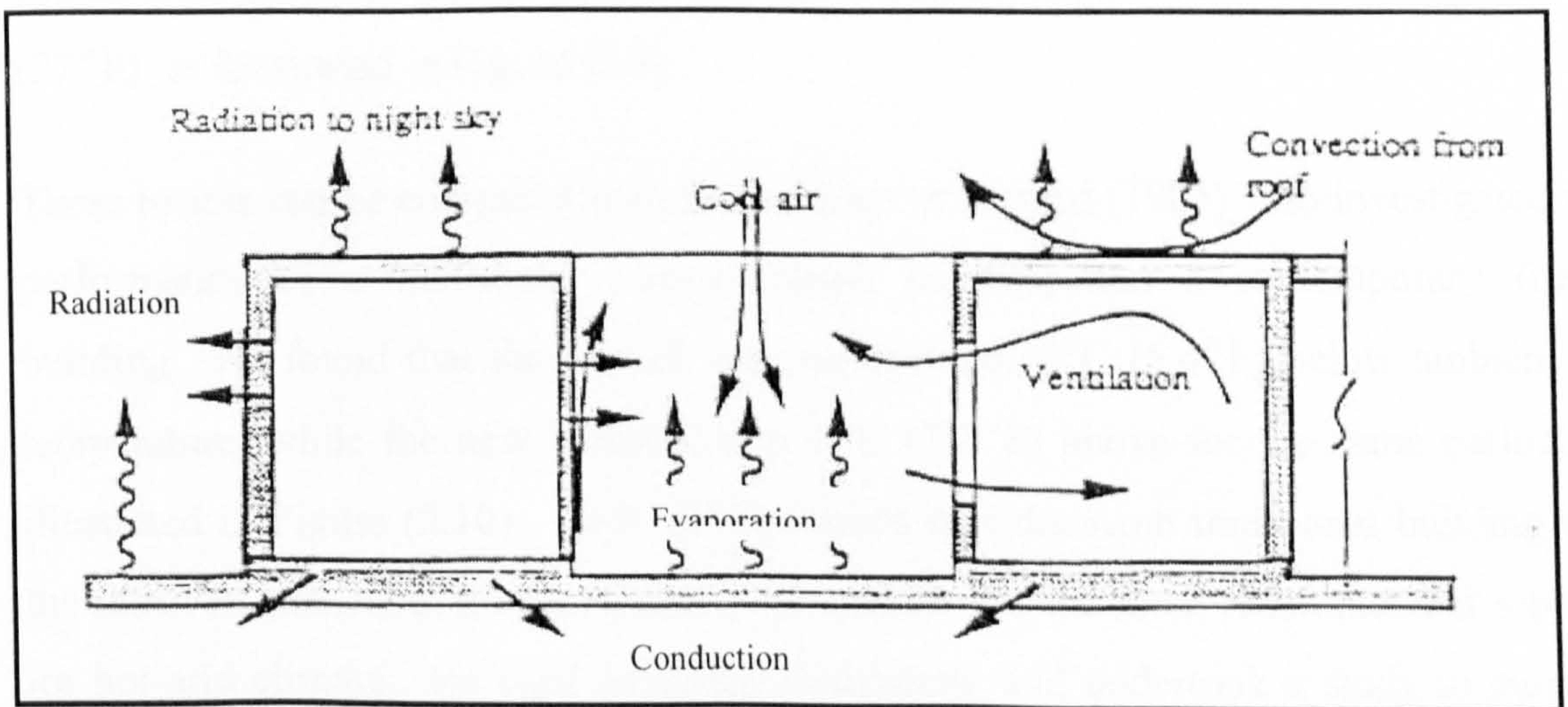


Figure 2.8: Nocturnal Cycle in the Courtyard Building.
Source: Al-Jared, M., (1991).

2.4.5 Literature Review on Traditional Building Performance

Many studies, such as Mohsen, (1979); Noor, M., (1986); and Fathi; Roaf, (1986) have conducted field measurements of socio-climatic which are consistent in traditional courtyard buildings. They have examined the performance of traditional houses, and have shown they vary greatly due to vary differences in materials, local climate, orientation, and in design details. Their studies suggest that the traditional houses outperform contemporary designs, simply because modern architects in the Arab countries ignored the crucial performance of the courtyard and failed to address the climatic variable. In addition, Olgyay, (1963); Szokolgy, (1980); Evans, (1980) and Cook, (1980) have stated that the courtyard house is recommended for the following reasons: the compact house form reduces the external surface area, and consequently overall solar heat gain is reduced; the house is closed to the outside (protection against the harsh external environment) and open onto a courtyard (a less harsh micro-climate); the courtyard attenuates the speed and penetration of the hot, dusty winds; the courtyard form reduces the penetration of solar radiation (more shaded surfaces). Furthermore, Nour (1979) stated that the air temperature inside a room in the courtyard building is cooler by between 1-3 °C (1.5-4.5 °F) than those in a modern air-conditioned. Danby (1986) also found that the temperature difference between air at the roof and the main reception in another courtyard house was about 11 °C (20 °F) between 2:00 and 4:00 p.m. Warren and Fathi, (1982) measured the temperature at different levels of a house in Iraq. They found that the differences between the air temperature at the roof and the lowest level (Serdab) was 20 °C (36 °F), and the difference at courtyard level was 15 °C (27 °F), as illustrated in Figure (2.9).

These results can be compared with the findings of Ahmed (1985) who investigated the performance of a traditional (conventional) building and a contemporary (new) building. He found that the former was, on average, 3 °C (5.4 °F) below ambient air temperature, while the new building was 4 °C (7.2 °F) above for the same period, as illustrated in Figure (2.10). Cook (1981) stated that the Arab traditional building and the introvert plan with its courtyard in the middle are the most recommended scheme for hot-arid climate. He used computer simulation, and undertook a study to monitor the effect of solar radiation on different courtyard geometry.

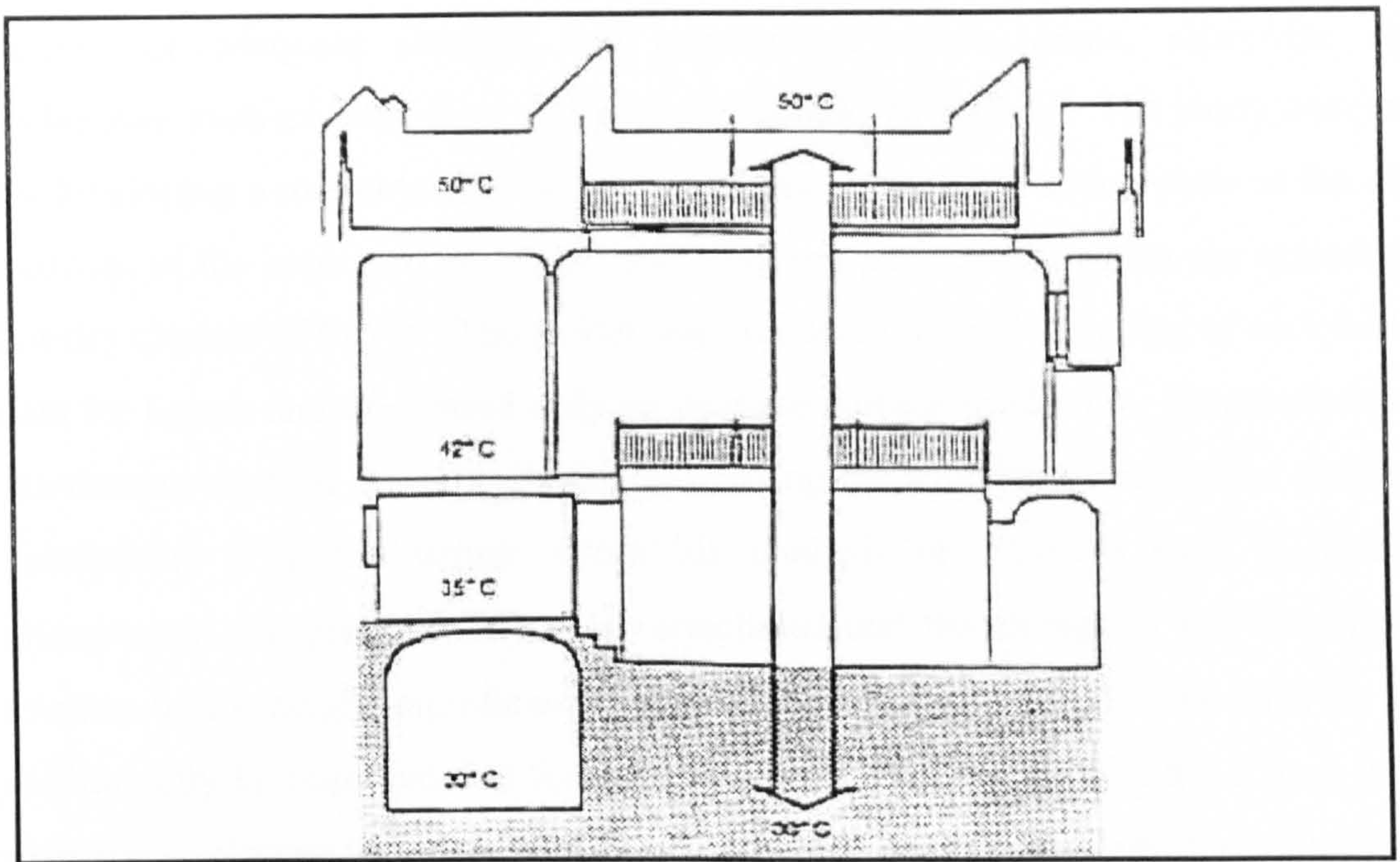


Figure 2.9: Temperatures at Different Floor Levels in a Courtyard Building, Baghdad. Source: Warren and Fethi, (1982).

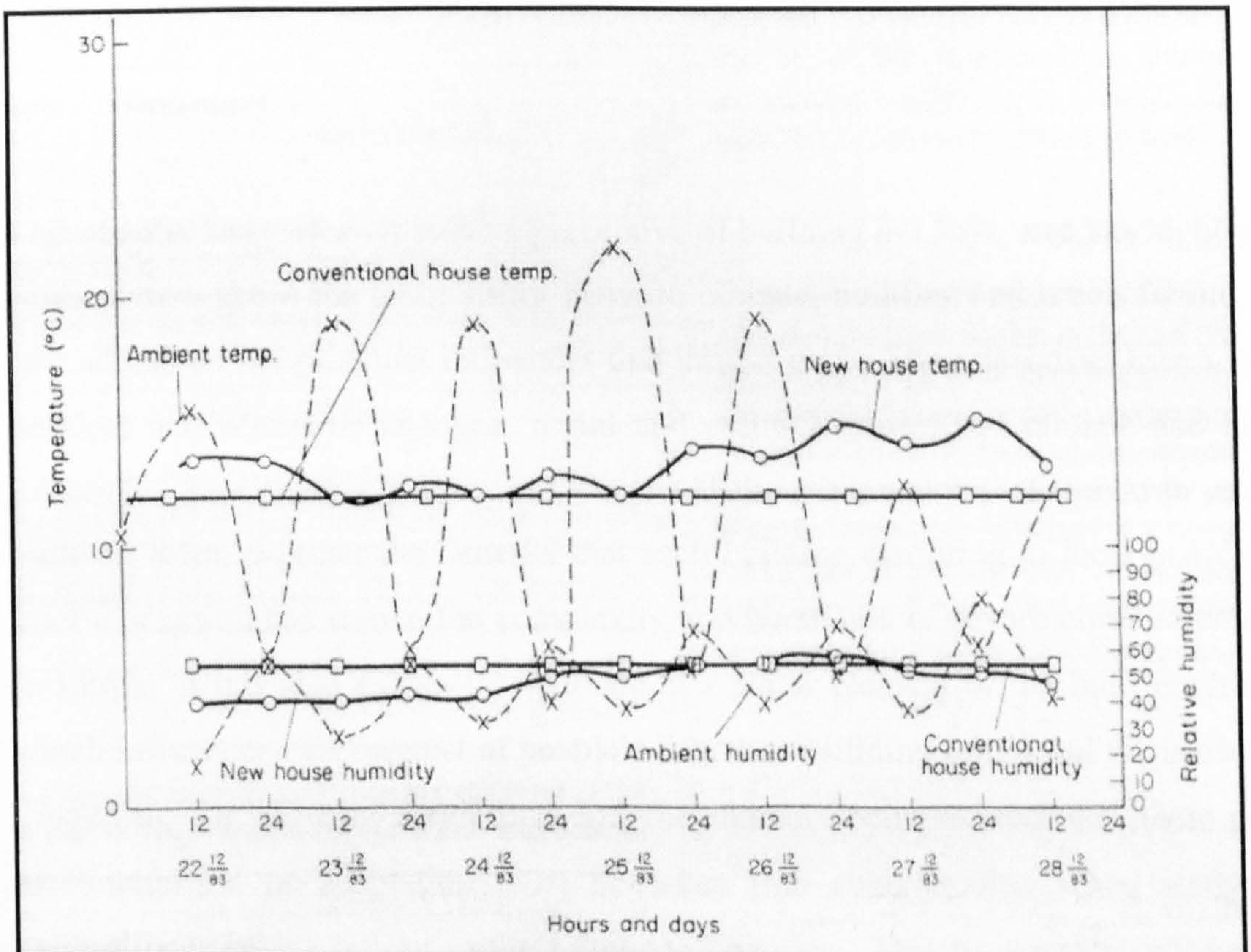


Figure 2.10: Temperature and Relative Humidity for Old and New Buildings in Ghadames. Source: Ahmed, S., (1985).

Mohsen (1979) recommended that the courtyard length in plan should not exceed its height for adequate shading and comfortable microclimate, otherwise shading techniques such as overhangs and pergolas should be utilised. His study concentrated on developing a model to simulate the radiation interactions taking place at the external surfaces of the courtyard envelope, and analysed parameters, which are typical for the hot-dry climate of Egypt. The model was run using monthly average of meteorological data for Egypt, and was based only on daytime surface irradiation. He concluded that a satisfactory thermal design calls for minimising the irradiation load in the summer and maximising it in the winter. From his analysis of different sizes of courtyards, orientations, and proportions he also concluded that the change of the court perimeter relative to its height significantly affects the irradiation load, especially in winter. Additionally he observed that for a one story building 3m. high and 2.5 m. x 2.5 m, in plan the minimum irradiation load occurred in the summer, while for a building 3 m high and 4.3 m x 10.7 m, in plan, which was elongated on the east-west direction, had the maximum irradiation load occurring in the winter. See Figure (2.10).

2.5 Summary

This chapter has given a historical perceptive of building in Libya, and has highlighted a general view about the relationship between climate, building and urban fabric. It has also addressed the principal influences that impact on building design in Libya, such as political and economic changes, social and cultural issues, and climate and building materials. Finally, this chapter has presented the main aspects of the Arab courtyard building form, together the benefits that such building can bring to local people. This brief discussion has shown the complexity and harshness of severe climatic conditions in Libya. It has also shown that climate is a major element of the built environment, which influences every aspect of people's life, their building forms and the urban fabric. Therefore, the climatic conditions and the human social aspects and their personal acclimatisation or adaptation must be taken into consideration when studying the thermal comfort, as set out in the following chapters. This background information is useful to get a clear picture about the country in which the case study of this project is located.

Chapter Three:
Thermal Comfort and the Building Environment

"The 24-hour cycle of the sun, the fundamental even which sets the rhythm of men's lives". Le Courbusier, as quoted by Besset, M. (1976: p160).

3.1 Introduction

People expertise, in controlling thermal environments in buildings has developed considerably in North African regions where the climate is hot and dry. Their predecessors sought thermal comfort through means such as sheltering in caves and tents, lying in the sun, sitting in the shade, wearing clothing made from animal skins. In learning how to light fire and build shelters or buildings, they made significant advances in the ability to provide a comfortable living environment.

The topic of thermal comfort has been the subject of much research. It is considered beyond the scope of this research to attempt to describe the factors, which affect human thermal comfort in any degree of detail. However, it is appropriate in the context of this research, to provide an overview of those factors, which affect thermal comfort, to assist with interpreting the review of the experimental procedures.

This chapter aims to provide a review of thermal comfort research. It begins by discussing the problem of defining and assessing thermal comfort using subjective rating scales. It then describes the derivation of several models employed by current standards and guidance to predict thermally comfortable environments. Finally, the chapter highlights the thermal comfort and its applications, especial emphasis of Fanger's PMV and Adaptive thermal comfort models, based on the findings of a literature review.

3.2 Overview of Thermal comfort

3.2.1 Defining Thermal Comfort

The American Society of Heating Refrigeration and Air-conditioning Engineers (ASHRAE, 1992) define thermal comfort as "that condition of mind which expresses satisfaction with the thermal environment", and as such will be influenced by personal differences in mood, culture and other individual, organisational and social factors. Thus thermal discomfort within building environments is a prevalent and significant issue throughout the developed and developing countries. However, thermal comfort is partly subjective – not every one will agree on what environmental conditions are comfortable, simply because this feeling is personally various from one person to another. Thus, it is not completely within the control of the building designer. Achieving 100% satisfaction with the comfort level of all occupants is very difficult for the designer or architect, but not impossible.

The thermal comfort standards prescribed by ISO 7730 (1995) are the first that have been used on a world-wide basis. They are based on Fanger's work in climate chamber experiments on young Danish students and lead to the PMV model. ASHRAE rather psychological definition of thermal comfort is generally accepted by the research community and practising engineers, and is quoted in current standards on thermal comfort e.g. ASHRAE 55 (1992) and ISO 7730 (1994).

Heijs (1994: 41) comments that "this description seems to be quite precise but it is not". He explains that from a psychological point of view it does not indicate what condition of mind is being referred to and whether it is a perceptual process, a state of knowledge, an attitude, cognition, or a general feeling. Also, the definition provides no indication of how to convert the mental state into a suitable measuring instrument. Therefore, he further states that "when comfort is regarded solely as a subjective mental state it seems elusive, both because it can not be measured objectively and because it is continuously changing".

Furthermore, he explores the linguistic and philosophical problems associated with assigning comfort to a condition of mind. For instance, if a person is in a room in a state of thermal comfort but then leaves the room, then the room loses its properties of thermal comfort, according to the previous definition. The interpretation of comfort as an environmental property has more advantage for the purpose of standards and engineering guidance. Nevertheless Heijs concludes that this produces another problem, as thermal comfort is not easily identifiable as a single variable that can be easily and objectively measured. Hence, the dependent variable in research tends to be a correlate of thermal comfort, e.g. a subjective rating.

3.2.2 Thermal Comfort Scale

The thermal comfort standards aim to predict the environmental conditions required eliciting thermal comfort in the majority of occupants. Thermal comfort tends to be practically expressed in terms of the ASHRAE 7-point thermal sensation (TS) scale (1966) or Bedford (TS_B) scales (1936). McIntyre (1982) states that "it is conventionally assumed that a person voting 3, 4 or 5 on either of the two 7-point scales finds his environment comfortable", but he said "this needs to be demonstrated". The index of ISO 7730 recommends that the environmental conditions produce less than 10% dissatisfaction. ASHRAE 55 also recommends similarly a limit of general discomfort of 10%.

Fanger (1970) derives a relationship between the mean thermal sensation vote for a group of people and the percentage dissatisfied within that group. His results show that 10% dissatisfaction corresponds to a mean thermal sensation of -0.5 to +0.5. Therefore, the range of room temperatures which produces the previous mean votes is generally termed the comfort range. The neutral temperature (t_n) is sometimes referred to as the comfort or optimum temperature, in which the occupants feel 'neutral' in that room (i.e. 0 on the ASHRAE 7-point scale). In addition to that, McIntyre (1980) and de Dear (1985) have used another rating scale named as preference scale (TP) in their field studies. Table 3.1 shows these three scales, the ASHRAE and Bedford sensation scales, and McIntyre and de Dear Preference scales.

McIntyre (1980) provides a detailed introduction to the problems associated with different types of thermal comfort scales. He points out, in his book, that the ASHRAE scale has the "advantage over the Bedford scale that it refers strictly to thermal sensation, while the Bedford scale confounds warmth and comfort and employs evaluative terms such as 'too'". But, both scales produce similar results in practice. There is an argument by Oseland (1994) that "it could be both scales are measuring a similar concept then both are measuring thermal comfort, but alternatively it could equally be argued that both are measuring some concept other than thermal comfort".

However, the adaptation model could be enhanced to distinguish between the physical (thermal sensation) and psychological (comfort) aspects of thermal comfort. The existing standards refer to the ASHRAE thermal sensation scale (TS) to express thermal comfort, which have been derived from experimental works. Recently, field researchers have used the ASHRAE scale to assess comfort to compare their findings to existing standards, such as Humphreys (1975), Oseland (1994), de Dear (1986), Nichol (1994), Malama et al (1998), etc.

Table 3.1: The ASHRAE, Bedford and Preference scales.

Point	ASHRAE(TS)	Bedford (TS_B)	Preference (TP)
+3 (7)	Hot	Much too warm	Much cooler
+2 (6)	Warm	Too warm	Cooler
+1 (5)	Slightly warm	Comfortably warm	Slightly cooler
0 (4)	Neutral	Comfortable	No change
-1 (3)	Slightly cool	Comfortably cool	Slightly warmer
-2 (2)	Cool	Too cool	Warmer
-3 (1)	Cold	Much too cool	Much warmer
Shading areas indicate points synonymous with comfort (McIntyre, 1980).			

Oseland, (1997: 5) states that "Thermal comfort is defined as a particular state of mind but in practice is considered equivalent to a vote on any of the three central categories of the ASHRAE thermal sensation scale". Therefore, these central categories, such as 'neutral', 'slightly warm', or 'slightly cool', could give an implication for designer or architects to know under which conditions people are thermally comfortable.

3.2.3 Theoretical Models of Thermal Comfort

Various attempts have been made to develop models for predicting thermal comfort. The theoretical models of thermal comfort are fundamentally based on thermal exchange theory and mechanisms for providing heat balance. Thermal exchange theory is concerned with the physics of how heat is transmitted from a body or maintained by a body in order to achieve thermal balance between the human body and the environment. Many studies on this field, such as Gagge (1937) and Fanger (1970), adopted this theory as the basis of producing and calculating a thermally comfortable environment for people. The heat exchange theory has been explained by Fanger (1970: 22):

> "Since the purpose of the thermo-regulatory system of the body is to maintain an essentially constant internal body temperature, it can be assumed that for long exposures to a constant (moderate) thermal environment with a constant metabolic rate, a heat balance will exist for the human body i.e. the heat produced will equal heat dissipation and there will be no significant heat storage within the body."

The human body is regarded as producing heat by increased activity (i.e. metabolic rate, met) and maintaining heat by clothing insulation (I_{cl}). Nevertheless, McIntyre (1980) mentions that heat loss from the body happens either: by radiation to the surrounding surfaces; by evaporation of moisture (latent heat); or by convective heat transfer to the surrounding air. McIntyre (1980) and Parsons (1993) provide a comprehensive review of such models. Parsons explains that there are two types of thermal index: the direct indices such as operative temperature which use instruments to simulate the human response, and the rational indices which use heat transfer equations such as effective temperature index (ET^*) and Fanger's PMV model. However, Humphreys (1994) mentioned that reported TS is correlated as highly with indoor air temperature as with the thermal sensation predicted from models. Further more, he argues that this result indicates that air temperature is as good a predictor of TS as the more complex models in any given context.

3.2.3.1 <u>Two-node Model of Thermo-regulation and Effective Temperature</u>

Gagge, et al (1971) derived a new effective temperature index of thermal comfort (ET^*), which developed from physiological research on thermo-regulation. Gagge (1937) and Gonzalez et al (1973) found a relationship between TS, skin temperature (t_{sk}), skin wettedness (w) and operative temperature (t_o). Operative temperature is defined in ISO 7730 (1994) that "the uniform temperature of a radiantly black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment". They stated that (w) is an excellent predictor of discomfort during regulatory sweating, which they defined as the ratio of actual evaporative loss at skin surface to the maximum loss that could occur in the same environment. Furthermore, they discovered that (t_{sk}) changes very little with changes in (t_o) when evaporative regulation can maintain heat balance. After that, they manipulated the thermal conditions to find out which combinations of temperature and humidity would produce same values of (w) and (t_{sk}) which represented the state of heat balance and TS. Gagge's results of his experiments were used to determine a range of ET^*. ASHRAE (1992: 4) has defined ET^* as "the operative temperature (t_o) of an enclosure at 50% relative humidity that would cause the same sensible plus latent heat exchange from a person as would the actual environment." Since then it has been used to prescribe a range of comfort conditions under certain clothing and activity conditions represented as straight lines on a psychrometric chart, as shows in Figure 3.1.

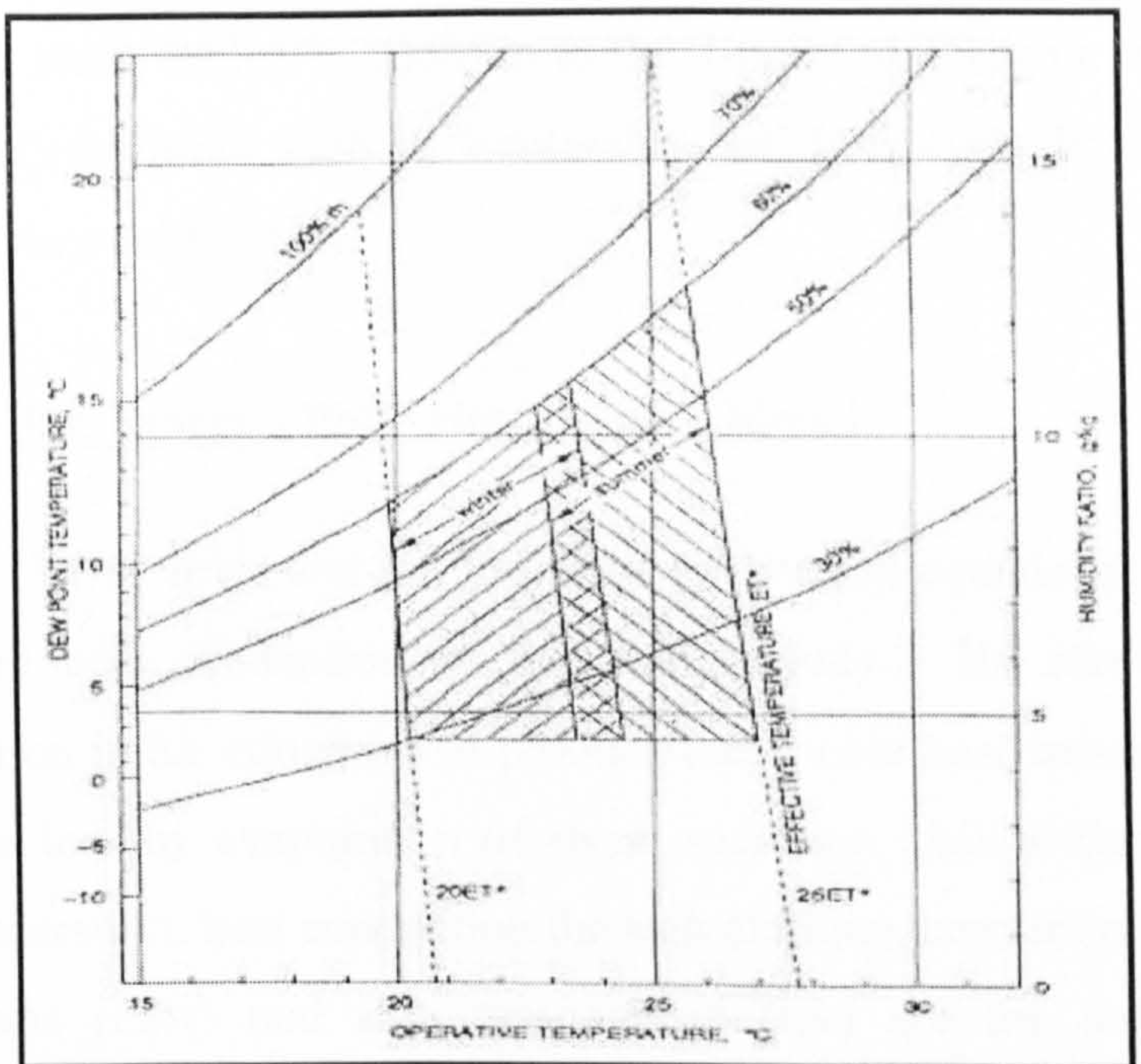


Figure 3.1: psychrometric chart for acceptable range of operative temperature and humidity for people in typical summer and winter. Source: ASHRAE 55 (1992).

ASHRAE (1992) defined the Standard Effective Temperature (SET) as:

> "... the temperature of an isothermal environment which has air and mean radiant temperature equal to each other, a relative humidity of 50% and still air, in which a person with a standard level of clothing insulation would have the same heat loss at the same skin temperature and the same skin wettedness as he does in the actual environment and clothing insulation under consideration."

ET^* is considered a rationally derived index formulated from the physics of heat transfer rather than from subjective estimates as in the development of the original ET. However, Gagge et al (1971) did not conduct actual experiments to determine the affect of the thermal conditions on (w) and (t_{sk}) but modelled the effect. In fact, ET^* was used to develop ASHRAE 55, but ET* relates room temperature and humidity to TS to provide an index for sedentary persons in standard clothing only. The standard effective temperature (SET) therefore was developed to incorporate different activity levels and clothing insulation. Nevertheless, SENS has been used with this two-node heat balance model in conjunction with empirical expressions to enhance the Gagge's model to predict thermal sensation. ASHRAE (1993, p8.17) has defined TSENS in terms of deviations of mean body temperature (t_b) from cold and hot set points representing the lower and upper limits for the zone of evaporative regulation. TSENS is predicted on an 11-point scale, which in addition to the 7-point at TS scale there are extra terms at the extremes conditions such as 'intolerably hot' (+4), 'very hot' (+5), 'intolerably cold' (-4) and 'very cold' (-5).

3.2.3.2 The Fanger's PMV Heat Balance Model

Fanger (1970) reviewed the literature to develop equations to model the internal heat loss and heat production of the human body. He combined heat loss and heat production in his equations to produce the double heat balance equation. He modelled the heat loss by evaporation of sweat secretion, skin diffusion, dry respiration, latent heat respiration, heat conduction through clothing, convection, and radiation. The sweat secretions (Esw) and skin temperature (tsk) are the only physiological variables influencing heat balance in that equation (see Figure 3.2).

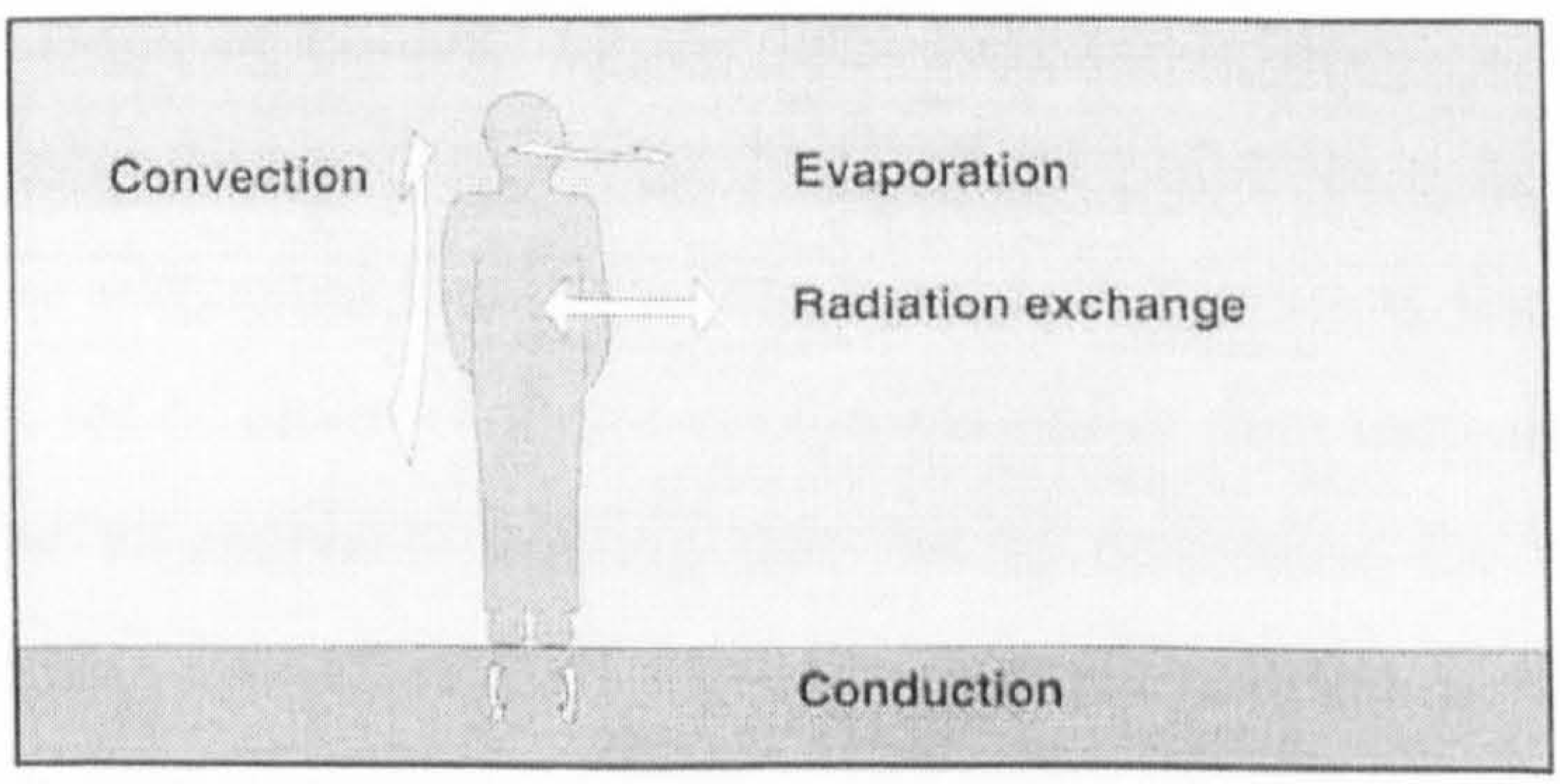


Figure 3.2: Heat Balance of the Human Body.

Fanger (1970) forms an equation of general heat balance, which can be used to calculate the environmental conditions required for comfort for a specific type of activity and clothing. Benzinger (1970) as quoted by Brager et al (1998; p84) has mentioned that:

> "heat balance models view the person as a passive recipient of thermal stimuli and are premised on the assumption that the effects of a given thermal environment are mediated exclusively by the physics of heat and mass exchanges between body and environment. The maintenance of a constant internal body temperature necessitates some physiological responses proportional to the thermal imbalance and it is generally assumed that thermal sensations (hot-warm-cool-cold) are proportional to the magnitude of these responses, as measured by mean skin temperature and latent heat loss or wettedness due to sweating".

These models are based on extensive and rigorous laboratory experiments and yield fairly consistent, reproducible results between climate chambers. The Fanger's PMV model (heat balance) referred to as the 'constancy' or 'static' model were the basis of the early pioneering work of Fanger (1970) and Gagge et al (1986: 709-731). Currently, both ASHRAE Standard 55-1992 (1992) and ISO 7730 (1994) are based on these works. The deterministic logic underpinning the heat balance comfort model is:

physics ⇒ physiology ⇒ subjective discomfort

Fanger (1970: 38) argued that "satisfaction of the heat balance equation is, however, far from being a sufficient condition for thermal comfort" and "within the wide limits of the environmental variables for which a heat balance will be maintained, there is only a narrow interval which will create thermal comfort". He explained that satisfaction of the comfort equation is a condition for optimum thermal comfort but the equation only gives information on what combination of variables is required for comfort and it does not directly predict the level of thermal comfort of a person. Hence, he explored a means of connecting the heat balance equation with thermal comfort assessed using subjective ratings on the ASHRAE 7-point scale, as shown in Table 3.1. Furthermore, he suggested that it was more important to know the number of people dissatisfied with a set of environmental conditions rather than their mean thermal sensation vote. Thus, he re-analysed existing data set to determine the relationship between the predicted mean vote (PMV) of a group of people and the numbers dissatisfied. Then he used his results to derive an equation predicting the percentage dissatisfied (PPD) from the PMV indices. The PPD values were calculated from the number of subjects voting outside the central three categories on the ASHRAE 7-point scale (i.e. –3, -2, +2 and -3).

ASHRAE (1997: 8.17) has presented, in their 'fundamental handbook', the correlation between PMV and PPD, as shown in Figure 3.3.

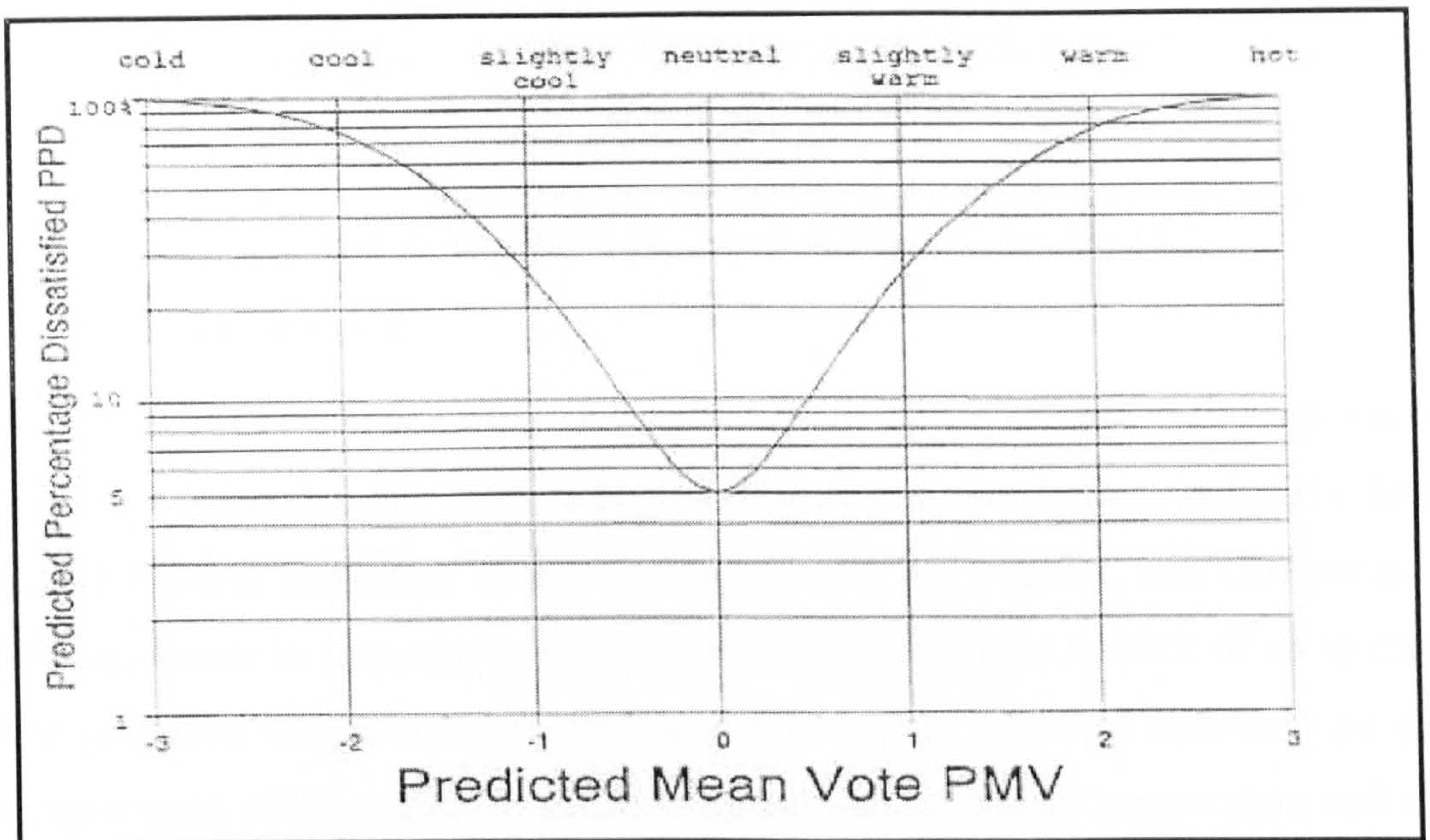


Figure 3.3: Predicted Percentage of Dissatisfied (PPD) as Function of Predicted Mean Vote (PMV). Source: ASHRAE, Fundamental Handbook (1997).

Despite the complexity of Fanger's comfort equation, PMV is dependent on only six main parameters:

a) Two personal parameters, i.e. metabolic rate (met) and the thermal resistance of clothing (clo).
b) Four physical parameters, i.e. inside air temperature (t_{in}), air velocity (v_a), relative humidity (Rh) and mean radiant temperature (t_{mr}).

The four physical variables can be measured accurately using standard instruments (see chapter 6, section 6.2), whilst the other personal variables are difficult to measure and are therefore estimated using tables providing the values for a range of activities and clothing attire. All of these parameters are described in section 3.4.

3.2.3.3 <u>The Adaptive Model</u>

More recently, Humphreys developed another model, known as the adaptive model. Humphreys (1975) suggested in the adaptive hypothesis, from about 35 field studies from Asia, Europe, and Australia, ranging from winter in Sweden to summer in Iraq, that the neutral temperature was related to the mean indoor air (t_{in}), or globe temperature (t_g). The current analysis of data is based on the same approach, which means that the neutral temperature, t_n, is the globe temperature when the actual mean vote (AMV) has a value of 0, see Figure 3.4. Then Humphreys (1976) developed the following linear regression to predict the neutral temperature:

$$t_n = 2.56 + 0.831\, t_{in} \quad (r = 0.96) \longrightarrow (3.1)$$

where t_n and t_{in} are in °C.

Humphreys (1978) stated that "the neutral temperature follows the actual value rather than the tabulated value. This is because the neutral temperature is largely determined by the thermal insulation of the clothing people are wearing, and changes of normal clothing levels in response to changes of temperature take a week or so to complete". The predicted neutral temperatures applies to lightly active or sedentary people in an environment with a natural ventilation system, where the air temperature and the mean radiant temperature are approximately equal and the air movement slight. He calculated the indoor air temperature (t_{in}) as a function of the outdoor air temperature (t_{out}) to be:

$$t_{in} = 14.1 + 0.55\, t_{out} \longrightarrow (3.2)$$

where t_{in} and t_{out}, are in °C.

The dependence of neutral temperature on mean outdoor temperature suggests that acclimatisation to the prevailing climate strongly influences thermal comfort. He calculated comfort temperatures reported by subjects in surveys in free-running buildings and heated or cooled buildings (see Figure 3.5).

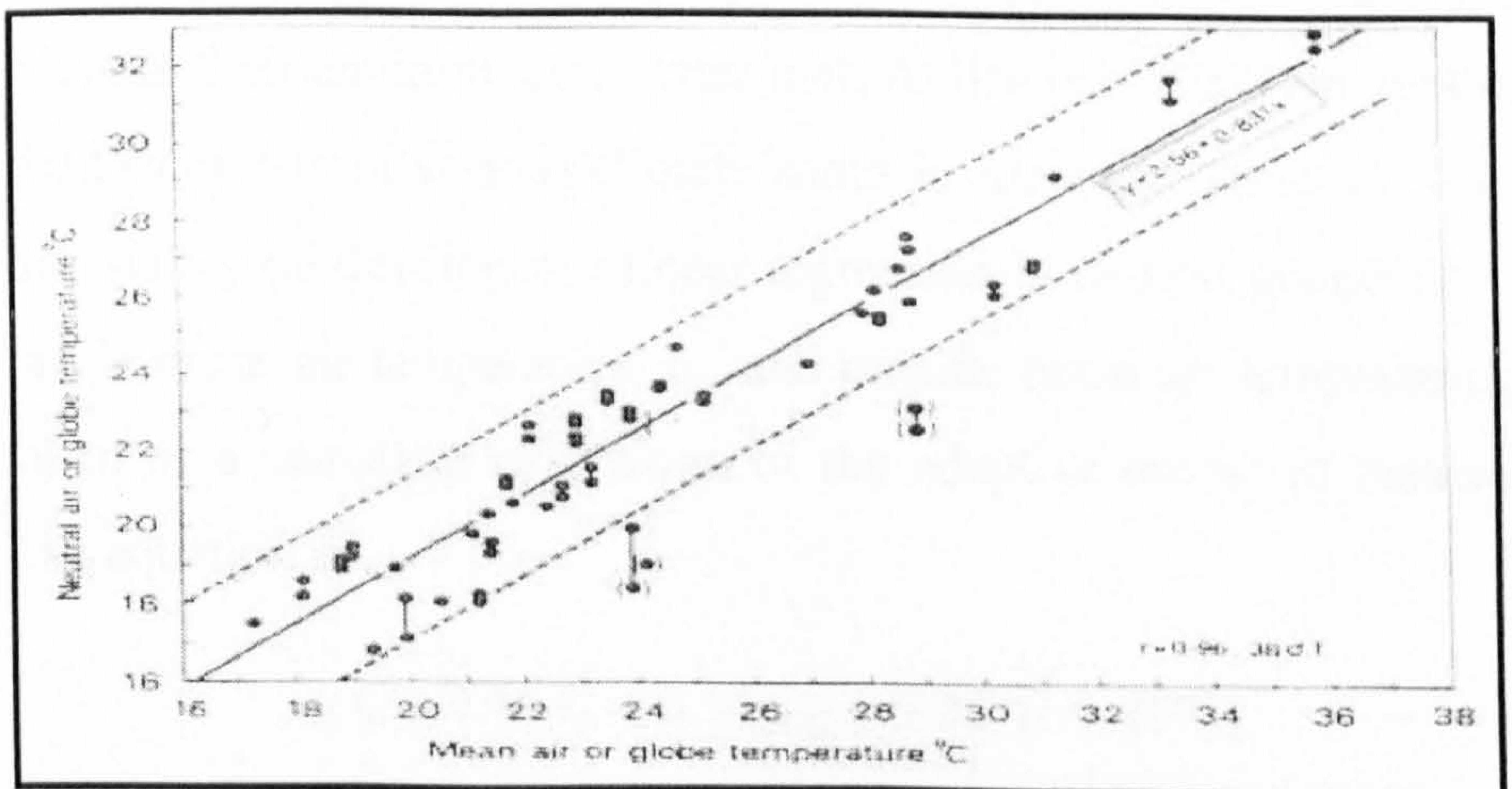


Figure 3.4: Scatter Diagram of Mean Inside Air or Globe Temperature and Neutral Temperature. Source: Humphreys (1976).

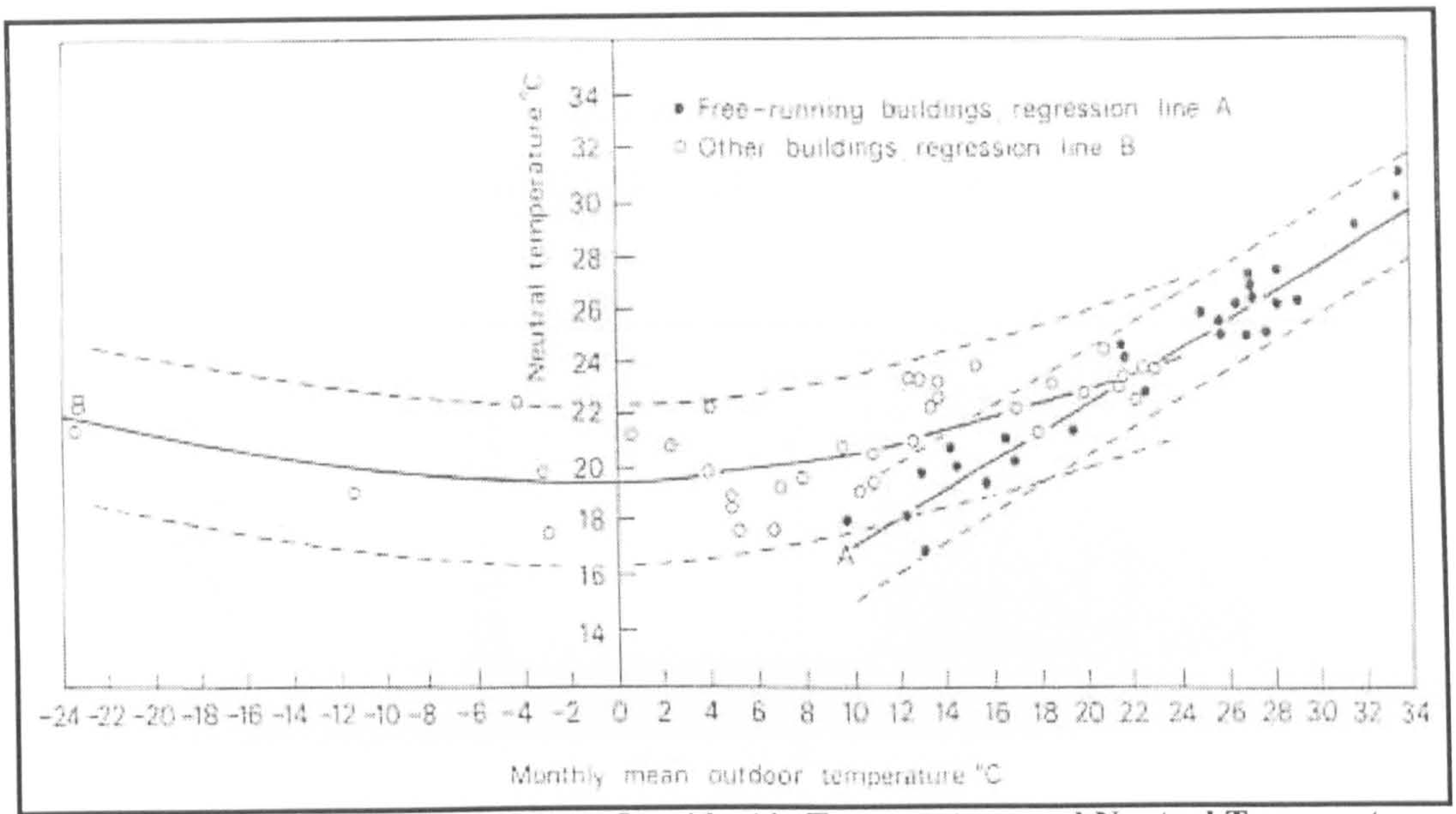


Figure 3.5: Scatter Diagram of Mean Outside Air Temperature and Neutral Temperature. Source: Humphreys (1978).

In a subsequent study, Humphreys (1978) demonstrated that the mean indoor temperature as experienced by the participants inside the buildings is strongly related to the mean outdoor temperature, t_{out}. He then derived a statistical relationship between the neutral temperature, t_n, to outdoor mean air temperature, t_{out}, (see Figure 3.3), through the following equation:

$$t_n = 11.9 + 0.534\, t_{out} \quad (r = 0.97) \longrightarrow (3.3)$$

where t_n and t_{out} are in °C.

As a consequence, this equation indicates that t_n will vary from one climate to another, reflecting the evidence that people will adapt different feedback methods in order to adapt to their environment. After that, Auliciems (1983) brought data from 53 separate field studies from various climate zones in Australia, America, Asia and Europe. From this survey he developed a linear regression of neutral temperature, t_n, as a function of inside mean air temperature, t_{in}, and outside mean air temperature, t_{out}. This has been taken as a statistical expression of the adaptive model of human thermal perception. The equation is:

$$t_n = 0.48\, t_{in} + 0.14\, t_{out} + 9.22 \quad (r = 0.97) \longrightarrow (3.4)$$

where t_n and t_{out} are in °C.

3.3 Parameters of Thermal Comfort

As mentioned earlier the main parameters affecting thermal comfort in the PMV model include environmental factors that are personal (two) and physical (four), as shown in Figure 3.6. They are described in the following sub-sections.

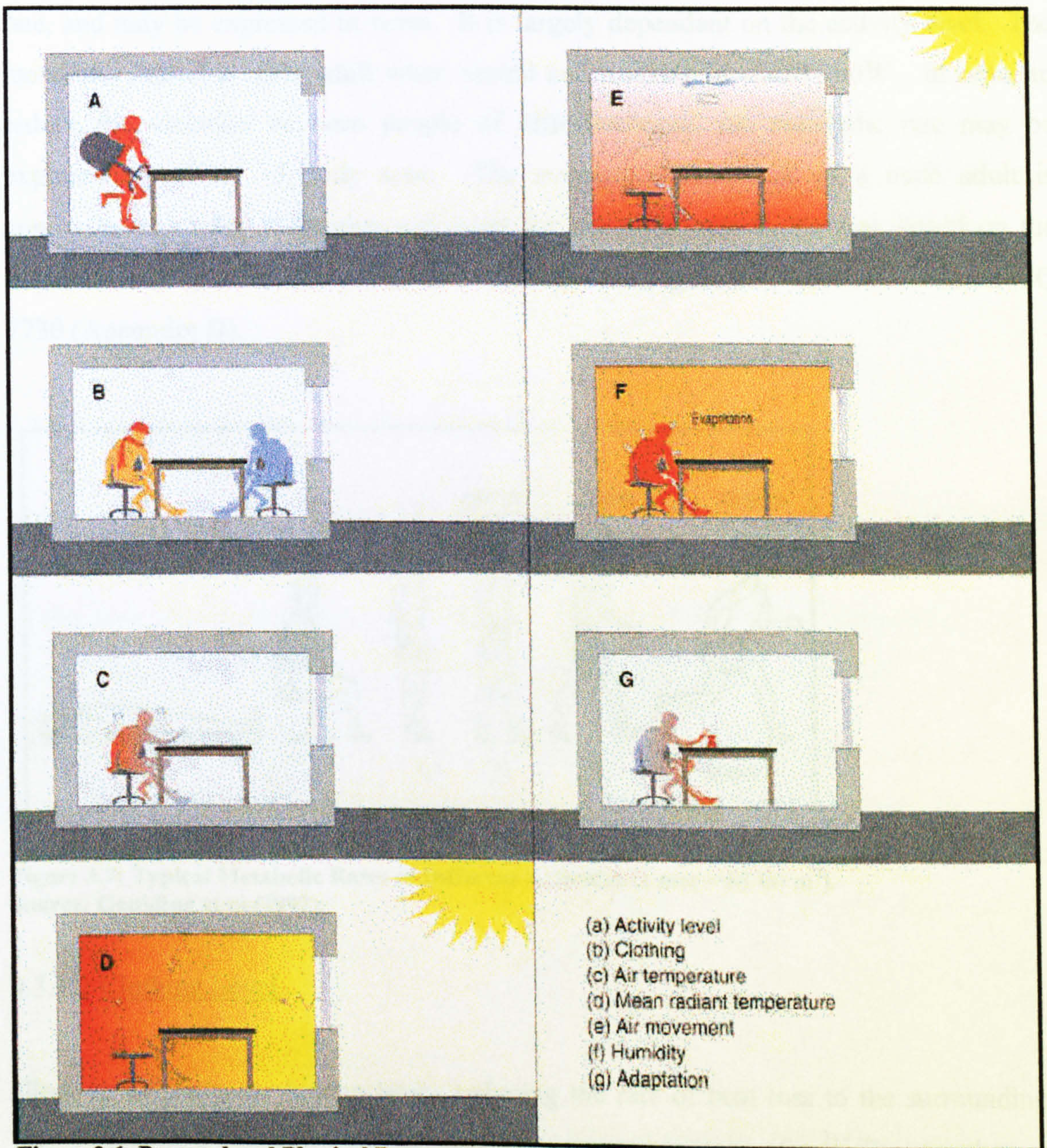


Figure 3.6: Personal and Physical Parameters Affecting Thermal Comfort and Adaptation. Source: Goulding et al (1992).

3.3.1 Personal Parameters

3.3.1.1 Activity Level

The rate at which energy in food is converted to heat in the body is called the metabolic rate, and may be expressed in watts. It is largely dependant on the activity level. The metabolic rate of a male adult when seated and relaxing is about 100W. In order to reduce the variation between people of different sizes, the metabolic rate may be expressed in W/m^2 of body area. The average surface area of a male adult is approximately $1.8m^2$. Another unit used for metabolic rate is the met, based on the metabolic rate of a seated person when relaxed. See Figure 3.7, which is based on ISO 7730 (Appendix D).

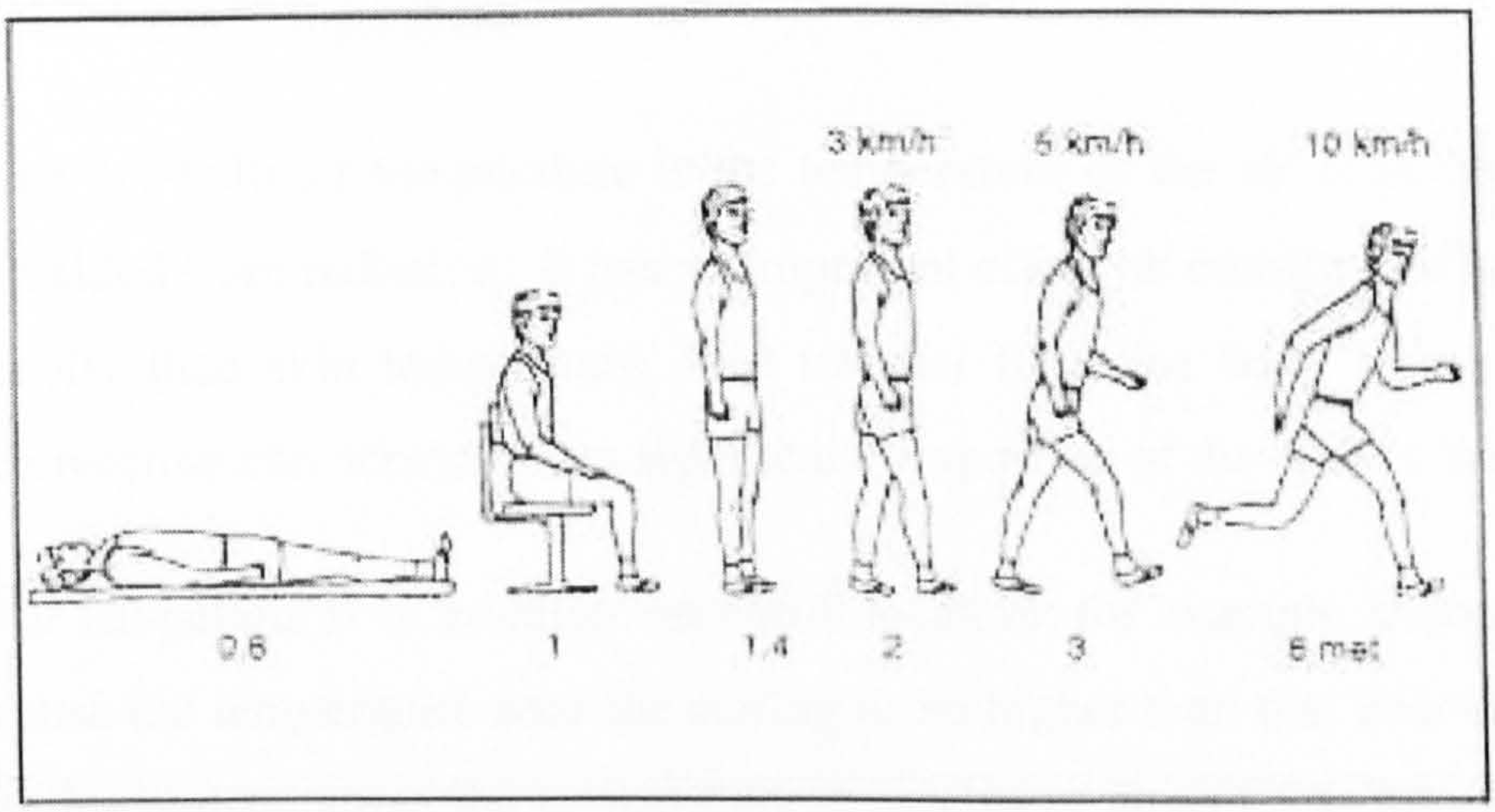


Figure 3.7: Typical Metabolic Rates of Different Activities (1 met = 58 W/ m²).
Source: Goulding et al (1992).

3.3.1.2 Clothing Level

Clothing insulates the human body, reducing the rate of heat loss to the surroundings. The thermal resistance of clothing may be expressed in units of m^2K/W. Another unit used is the clo. 1 clo corresponds to the thermal resistance of a typical winter business suit (1 clo = 0.16 m^2K/W). Typical values range from zero for a naked person to 3 or more for Arctic dress. Typical values of thermal resistance for various combinations of clothing are shown in Figure 3.8, which is based on ISO 7730 (see Appendix C).

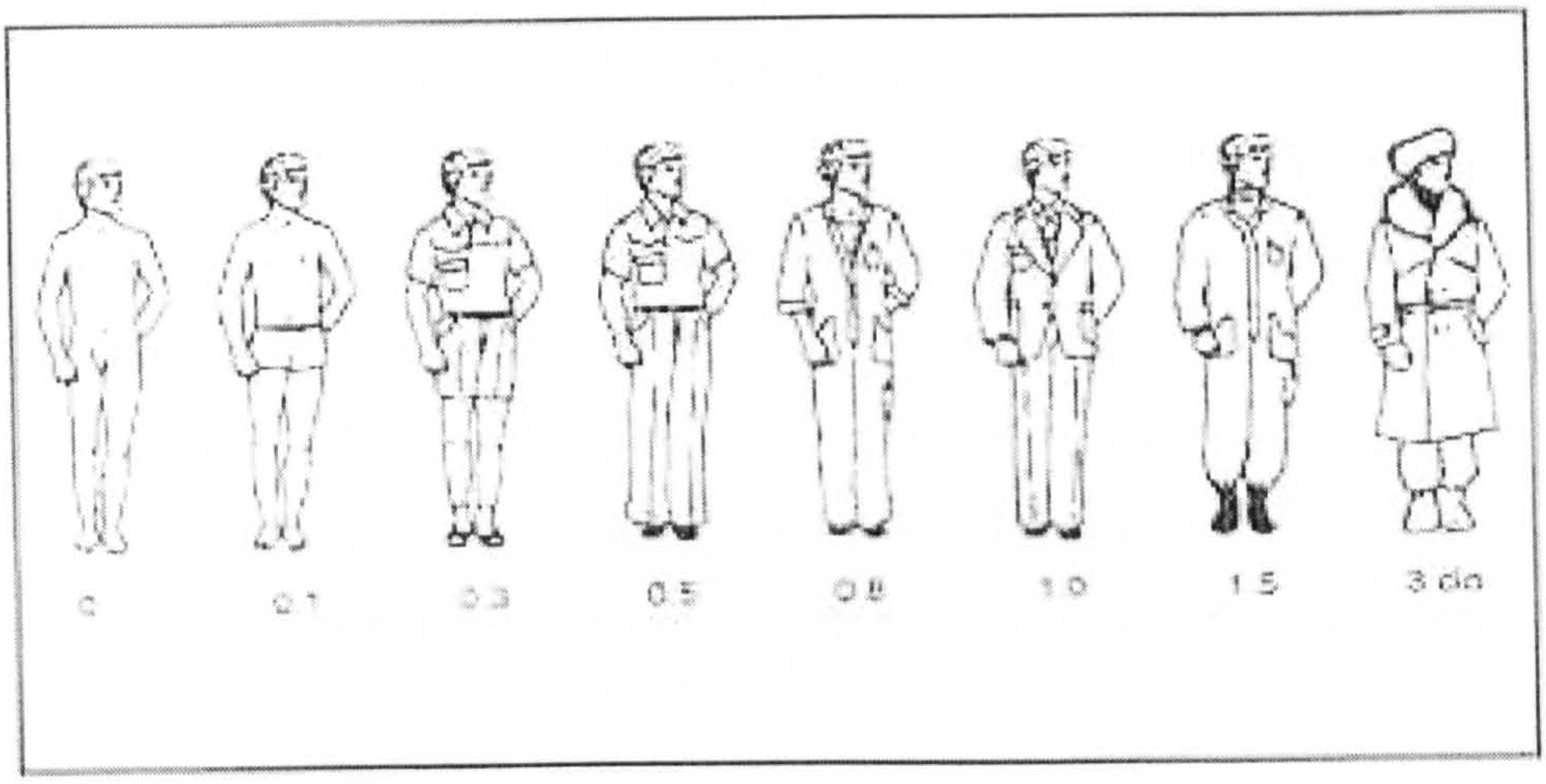


Figure 3.8: Thermal Insulation Properties of Typical Combinations of Clothing. Source: Goulding et al (1992).

3.3.2 Physical Parameters

3.3.2.1 Air Temperature

The dry-bulb air temperature is the temperature of the air indicated by a thermometer shielded from radiation. It has an important effect on comfort. When air temperature is cooler than skin temperature, heat transfer from the body to the surrounding air by convection can account for a significant proportion of the body's heat loss.

Air temperatures in building vary with location; for example, thermal stratification may cause the temperature near the ceiling to be higher than that near the floor. For people sitting and standing, the temperature at heights of up to 1.5 to 2 meters above floor level are of most interest. It is recommended in ISO 6242-1 (1992) that specified temperatures should apply on a plane 1m above floor level.

3.3.2.2 Mean Radiant Temperature

Radiation exchange between people and their surroundings is important also for thermal comfort. The mean radiant temperature is defined in ISO 6242-1 (1992) as the uniform surface temperature of a radiantly black enclosure in which the occupant would exchange the same amount of radiant energy as in the actual non-uniform space. (A radiantly black enclosure is a theoretical enclosure in which the absorptances and emittances of all enclosing surfaces are 1.0).

The mean radiant temperature depends on the temperatures, areas, absorptances, reflectances, emittances and transmittances of the surrounding surfaces, and their distances from, and orientations relative to, the point in question. It follows that the mean radiant temperature can vary from one place to another even in the same room. The concept of mean radiant temperature is usually measured with the help of a globe thermometer. This consists of a temperature sensor positioned at the centre of a blackened spherical copper shell. Once the globe temperature, the air temperature and air velocity known, the mean radiant temperature could be calculated.

3.3.2.3 Humidity

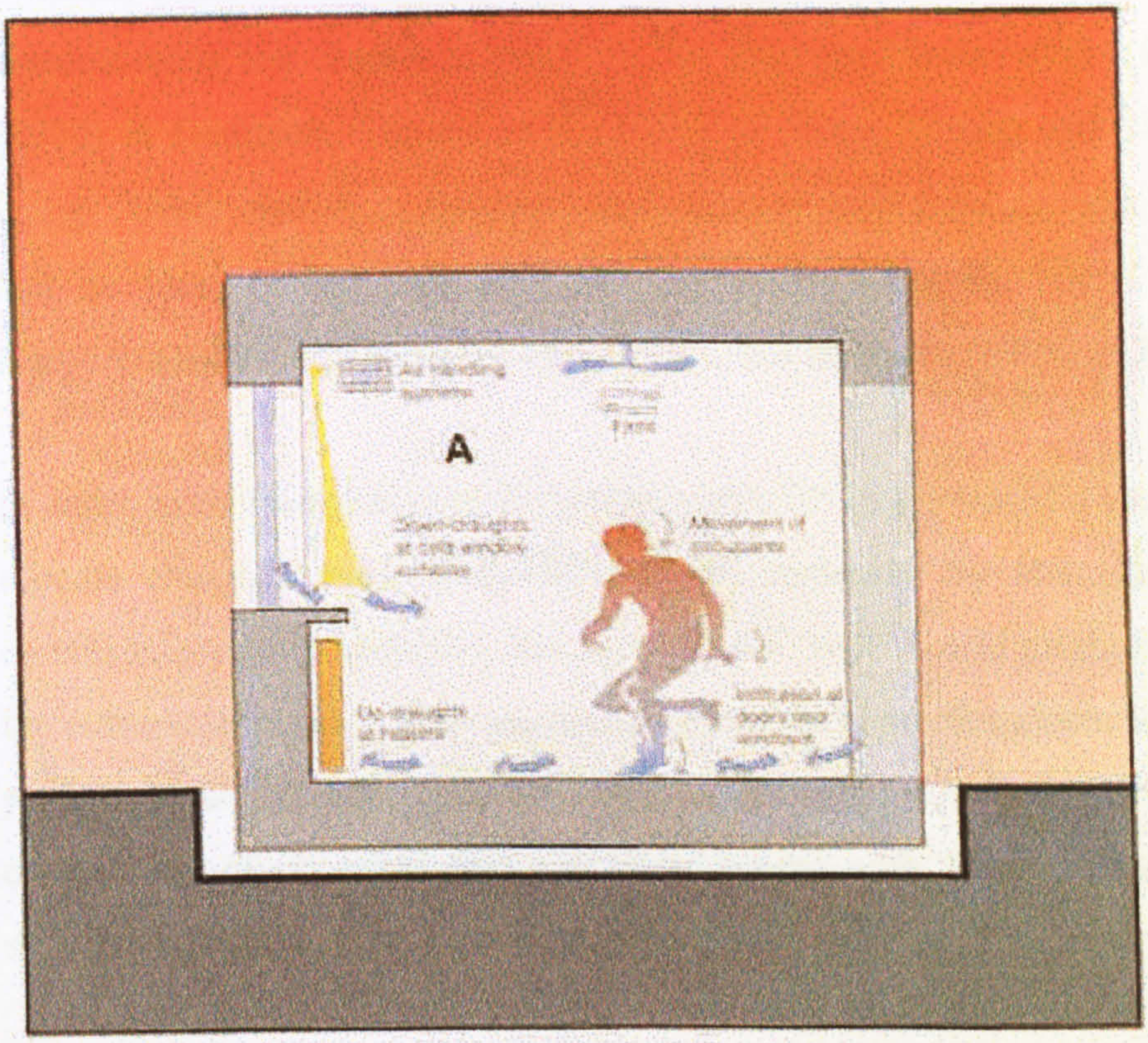
At moderate temperatures close to comfort conditions, the influence of humidity on thermal comfort is small, and may usually be neglected. Humidity affects the rate of evaporation of perspiration, and thus has an important effect on comfort in hot-dry climate. At a given high temperature, reducing the humidity will allow an increase in the rate of evaporative cooling of the body, thus improving comfort.

Even at moderate temperatures, there are a number of reasons why extreme levels of humidity are undesirable. Sustained high levels of humidity may give rise to mould growth and associated health problems. Very low values may give rise to dry throats and the build-up of static electricity. The latter can accumulate in the body leading to irritating shocks when the body touches an earth object. It is recommended in ISO 7730 (1994) that the relative humidity be maintained between 30% and 70%.

However, in non-air-conditioned buildings (i.e. natural ventilated buildings), appropriate air change rates and ventilation strategies should in most cases ensure that humidity-related problems do not occur.

3.3.2.4 Air Velocity

The air velocity or speed relative to the occupant affects both convective and evaporative cooling of the body. Relative air movement can be caused by infiltration, ventilation, convective currents caused by heat sources or vertical cold surfaces, air handling equipment, or the movement of occupants. Common sources of air movement however are shown in Figure 3.9.



Igure 3.9: Different Sources of Air Movement.

Air movement velocity reduced the thermal resistance of the air film next to the skin or clothing. When air temperature is below that required for comfort, an increase in air velocity will result in an increased rate of convective cooling, which the body senses as a cold draught. In hot/dry climate, for instance, increased air movement will increase the rate of evaporation of perspiration, thus helping to keep the body cool. However, if air temperature is higher than body temperature, there will be an optimum air speed above which convective heat gains will outweigh evaporative heat losses. Some air movement is needed around occupants to ensure a supply of fresh air.

3.4 Thermal Comfort and its Application

McIntyre (1980, p114) states that "... the thermal sense is not well behaved and the sensation felt by a person cannot simply be predicted by the temperature of the stimulus." Thermal comfort studies using field surveys and climate chambers have continued to present different results, and they could produce different results in different parts of the world. There have been extensive studies to measure thermal comfort using test chambers by others; for example Nevins et al (1966) in USA, Fanger (1970) in Denmark, Tanabe et al (1987) in Japan, Chung and Tong (1990) in Hong Kong. Other studies in thermal comfort have used field surveys such as - Auliciems and de Dear (1986), Abdulshakor (1993) in Malaysia, Nicol (1994) in Pakistan, Karyono (1995) in Indonesia, and Malama and Sharples (1998) in Zambia.

In addition to Humphreys (1975), McIntyre (1978) presented a comparison of Fanger's climate chamber work with field studies reviewed by Humphreys, suspecting that certain intervening variables that occur in the "real" world might not be reproducible in the climatic chamber. This suggests that, the field studies closer to the "real" world are preferable to climate chamber ones. Recently, Oseland (1997) made a general comparison of observed occupant requirement with those predicted and specified in standards in terms of thermal comfort.

3.4.1 Characteristics Overview of the Building and its Occupants

In the previous chapter, the implications of the outdoor climate on the aspects of thermal comfort have been described in detail. Humphreys (1994) explained that when attempting to achieve overall comfort and the various facets of the environment are not controllable (i.e. there are constraints). Then he said that the occupant might have to 'trade off' one kind of comfort against another, e.g. opening a window to cool down may let in too much noise. Wyon (1994) explained that thermal sensation must trade off such factors as convenience, economy and social consideration, against other factors such as fan noise, odour, allergy and SBS. Such factors were termed 'constraints' by Humphreys (1994), and each situation has a different set of constraints.

Figure 3.10 shows the main idea of 'trade off' to the building design, similar to the idea applied by Oseland (1993). The idea breaks down design criteria into 'requirements' (e.g. space, number of occupants) and 'components' (e.g. windows, heating/cooling system, number of rooms) and explains how the design of various components will conflict with the range of requirements. For example, the size and type of a window can directly affect heating/cooling, light, noise and ventilation. In the same way the design of the space and construction materials could also affect privacy, security and safety.

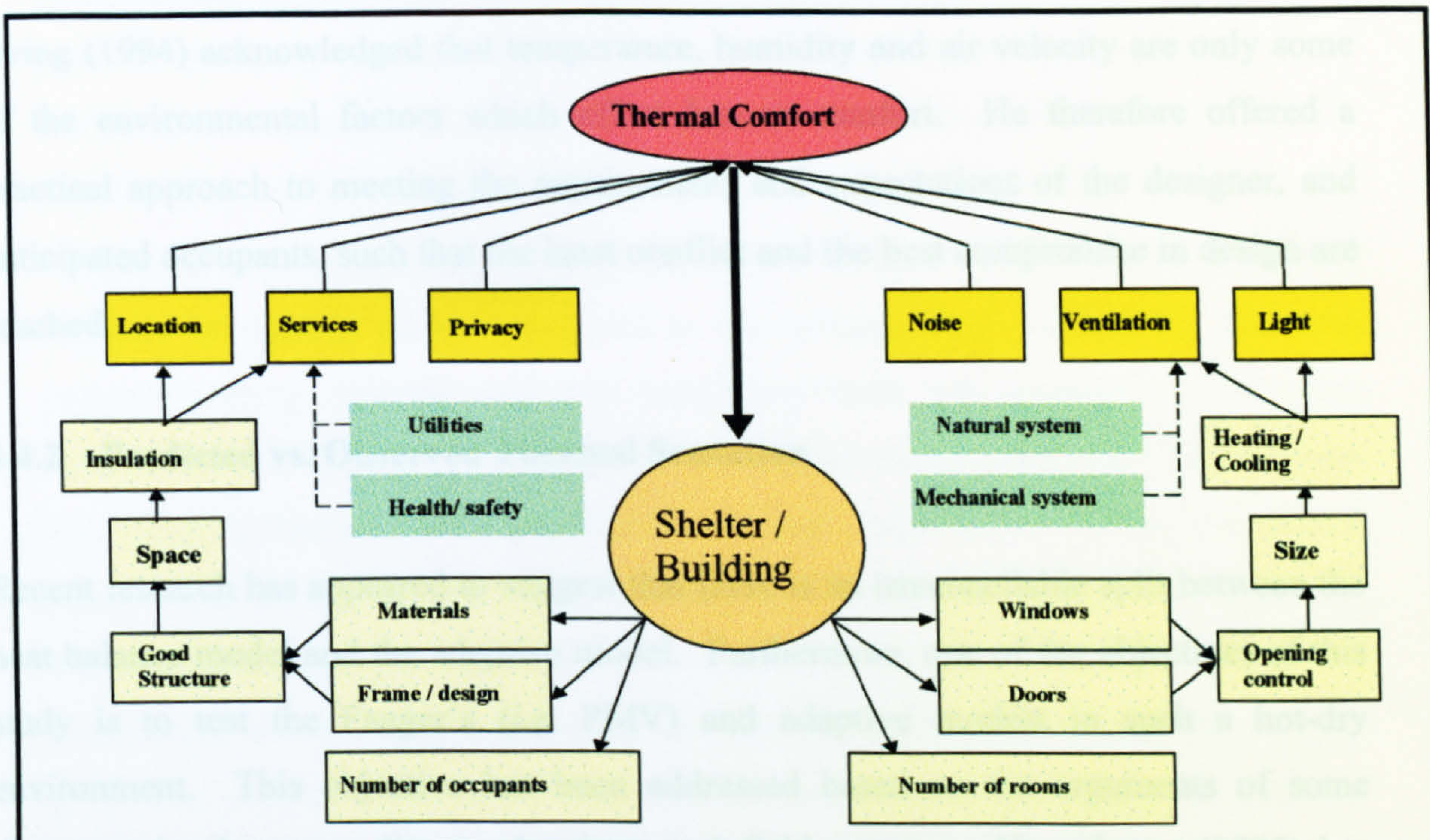


Figure 3.10: Main building components for shelter and its occupants requirements.

In the 20th century, technology lead to the widespread application of heating and cooling in the form of air-conditioning and an obsession with standardised comfort conditions has developed. This notion, that there is an optimum thermal environment is now deeply rooted and is strengthened by both field and chamber studies on comfort. However two factors have emerged which have re-opened the need to assess thermal comfort standards or models; a) the increasing demand for energy for air-conditioning has prompted research in passive cooling which in turn has required more flexible ways of assessing free running buildings. b) growing disenchantment with controlled air-conditioned new buildings and their association with sick building syndrome, and the observation that occupants more often like to be living in naturally ventilated buildings, has thrown doubt on the existence of these 'optimum' conditions. As a consequence, the critical issue is when comfort criteria are applied to the predicted thermal conditions in proposed buildings. These inappropriate comfort criteria maybe therefore lead the designer into adopting the high-energy air-conditioned path. So that once a building is built, the issue of comfort criteria becomes less contentious since the occupants can now make the ultimate judgement.

Irving (1994) acknowledged that temperature, humidity and air velocity are only some of the environmental factors which affect human comfort. He therefore offered a practical approach to meeting the requirements and expectations of the designer, and anticipated occupants, such that the least conflict and the best compromise in design are reached.

3.4.2 Predicted vs. Observed Thermal Sensation

Recent research has appeared to suggest that there is an irreconcilable split between the heat balance model and the adaptive model. Furthermore, one of the objectives of this study is to test the Fanger's (i.e. PMV) and adaptive models in such a hot-dry environment. This objective has been addressed based on the arguments of some discrepancies between climate chambers and field surveys. Humphreys (1995) has argued whether these laboratory-derived models can be applied, without modification, to describe real-world thermal perception. The PMV model has demonstrated some limitation when used as a design tool, when for instance, the designer has to anticipate what average user metabolic rate (met.) values and clothing insulation (clo.) might exist in a building which may not have been even built. Gagge et al (1976) and Rowe et al (1995: p59-69) stated that these models frequently still fail to accurately describe or predict thermal comfort, even when applied to occupied buildings where the crucial input parameters of clothing insulation and metabolic rate can be observed.

Garger et al (1998) addresses very important points from their wide range of literature reviews through the following points, considering wide discrepancies often found between predicted and observed mean thermal sensation.

a) Considering model inputs:

- Estimating insulation of clothing garments or ensemble; Brager et al (1994) demonstrated that the calculated clothing ensemble insulation value (clo) differs by as much as 20% depending on the source of the tables and algorithms commonly used the IS 7730 standard (1994) and ASHRAE Standard 55 (1992). In addition, clothing insulation measured under laboratory conditions with an inanimate thermal manikin may be different from in situ clothing insulation due to factors such as posture, pumping effect, different material fibres, vapour permeability, fibre thermodynamics under transient environmental conditions. Nielson et al (1985: p1617-1631) and McCullough (1994: p765-775)
- Estimating activity patterns and associated met level; one of the least-developed methods of thermal comfort research is the existing field method for assessing people's activity patterns and then translating them into metabolic rates using standard tables. This point is based on the arguments of Cena (1994) that factors that would influence the assessment of metabolic rate would include the mental stress related to a given task, transient effects of earlier activities, or the vigor with which a given activity is performed.
- Accounting for the chair insulation; At the ASHRAE Transaction 96, Schiller (1990), as well as Wyon and Fanger (1990), stated that the tendency for PMV to overestimate thermal neutralities in many field studies may be due to the systematic omission of the thermal effect that chairs have on their occupants. McCulough and Olesen (1994: p795-802) examined the effects of the upholstered office furniture on the total thermal insulation of a heated manikin and found that a typical office chair adds approximately 0.15 clo to the value that one gets by simple addition of individual garment values.
- Non-uniformities of physical measurements; Baker (1993) stated that field studies often take only spot-measurements of ambient thermal parameters and, if they happen to be slightly separated from the occupant's location in space and/or time, they might not be representative of the indoor microclimate actually experienced by the occupants. Brager et al (1998: p85) states more that this becomes particularly important in rooms with transient or specially non-uniform thermal conditions as is

often the case in passive, or naturally ventilated buildings, or any situations where workers have high levels of environmental control available to them.

b) Model assumptions – steady state vs. transient:

- Further more, Brager et al (1998: p85) in her review states that static heat models are based on experiments in steady-state conditions in the laboratory, whereas conditions in buildings are likely to be much more dynamic, in terms of both the thermal environment and the occupants' activities. Although more work is needed in this area, examples of preliminary studies as de Dear et al (1989: p336-350), suggest that clothing can significantly affect one's response to humidity transients. Ring et al (1991: p448-456) stated that the cold temperature transients give rise to a strong subjective response compared to warm transients of equal magnitude. In terms of human ecology, Mahdavi et al (1996: p179-182) mentioned that this variance is referred to as ecological valency and ecological potency, respectively. Nevertheless, Heijs (1994) concluded that this produces another problem, as thermal comfort is not easily identifiable as a single variable that can be easily and objectively measured. Hence, the dependent variable in research tends to be a correlate of thermal comfort, e.g. a subjective rating.

- Randall McMullan (1992: p56) stated that "A satisfactory thermal environment is an important purpose of good building design. To achieve an acceptable thermal environment we need to consider the thermal comfort of people using the building and the requirements of objects stored in the building". ... "The thermal comfort of human being is governed by many physiological mechanisms of the body and these vary from person to person. In any particular thermal environment it is difficult to get more than 50% of the people affected to agree that the conditions are comfortable".

Oseland (1995) has reported on significant discrepancies occurring between predicted mean votes (PMV) and actual mean votes (AMV) values obtained in offices and homes as compared with climate chamber studies, attributing the differences to contextual and adaptation effects.

Raw et al. (1994) mentioned that there are three main reasons for continuing research into thermal comfort:

a) because we do not yet have all the answers;
b) because there are new questions;
c) because there is still discomfort.

Points a) and b) may be sufficient to convince most researchers that further studies are required. Field studies show effects that are not found in climate chambers. A fieldwork on thermal comfort of the above type has not previously been attempted in Libya specifically or North Africa generally. Therefore, the present paper discusses the practical application of ISO 7730 Standard based on field experience carried out at Ghadames oases in Libya. It also presents human thermal sensation votes in both naturally and mechanically ventilated buildings.

ASHREA Standard 55-1992 (1992), and ISO 7730 (1994) state that existing standards which prescribe 'ideal' conditions for thermal comfort are based on a heat balance model of the human body and are derived from extensive experiments in climate chamber, conducted primary with university students in mid-latitude climate region. Although these standards were initially developed for centralised HVAC- controlled buildings, it is often suggested that they are universally applicable across all building types, climate and populations; Parsons, (1994: p184-197). However, Brager et al (1998: p83) states that "in practice, they provide little guidance for the design and operation of buildings that are either naturally ventilated, or provide occupants with other means of individual control over their thermal environment". This research therefore, will join other researchers in challenging this assumption of universal applicability only of both 'heat balance' model and 'adaptive' model, based on field survey in Ghadames oasis, Libya. Further more, Brager et al (1998) states that "a strict reliance on laboratory-based comfort standards ignores important contextual influence that can attenuate responses to a given set of thermal conditions. ... An entire issue of Energy and Buildings was devoted to the social and cultural aspects of cooling, including the variation among people in the perceived need or desire for air-conditioning".

3.4.3 Conceptual Method

Conceptual method deals in theoretical and conceptual discussion. However, the well being of occupants with respect to the dwelling is often expressed in terms of the satisfaction of their needs in the dwelling process. This formulation is adopted in the study, because the term 'need' has a connotation of necessity, similar to that of comfort. It has been stated by Heijs (1994: 43) that "... a property of the dwelling, which indicates how far it can, through possessing the necessary physical characteristics, satisfy the physiological and psychological residential needs of occupants during the dwelling process". The main objective of this Conceptual Method is the assessment of adaptive opportunity in different buildings and the correlation with subjective assessment of thermal satisfaction. The idea that adaptive exercise is a fundamental human need has been put forward, and the notion of neutrality being optimal has been challenged. The social scientific building literature deals with component properties or sub-field of residential comfort. Thus, the literature suggests a first, and perhaps somewhat artificial, distinctive physiological and psychological sub-field. Figure 3.11 shows the core of the theoretical model. Residential comfort as a whole is made up of the sub-fields and is isomorphic with the totality of residential needs. The presence of sub-fields is determined by the extent to which residential needs are satisfied and is influenced by the occupants' characteristics; and the dwelling's physical characteristics. Therefore, the relative importance of the various sub-fields for residential comfort as a whole is dependent on characteristics of the dwelling and its occupants.

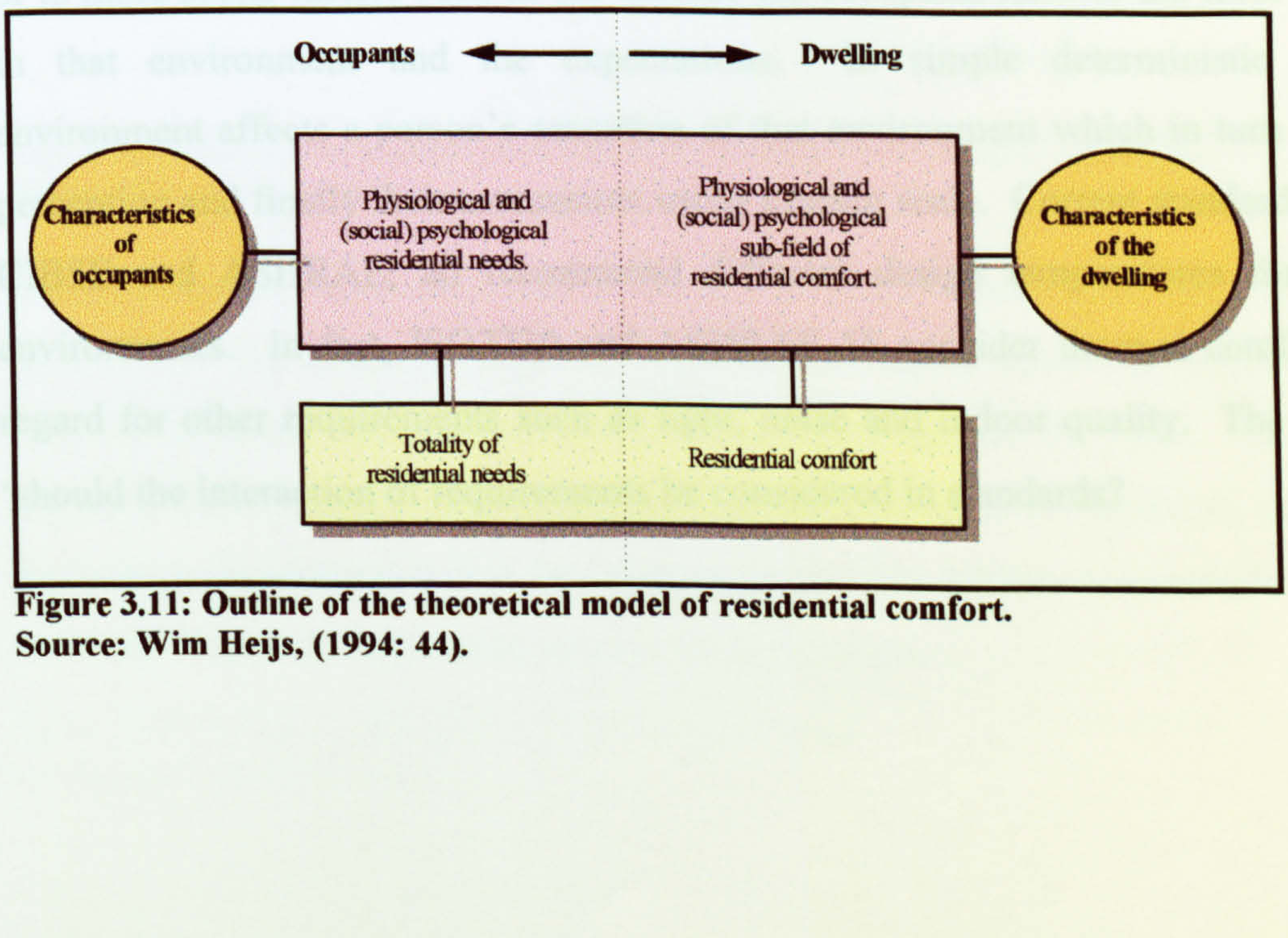


Figure 3.11: Outline of the theoretical model of residential comfort.
Source: Wim Heijs, (1994: 44).

3.4.4 Scientific Method

This method deals in the range of responses to each model in detail (i.e. Fanger's and Adaptive models) considering their main parameters and their differences. Fanger's PMV model considers heat exchange between man and environment, using the six parameters. It assumes that thermal comfort is defined in terms of the physical state of the body not the environment. Since the adaptive model was shown to be valid for hot-dry climates, the reasons behind that need to be investigated.

The main parameter which the adaptive model is based upon, is represented by the algorithm derived by Auliciems (1983) to calculate the neutral temperature (t_n) as a function of both average inside air temperature (t_{in}) and 'average outside air temperature' (t_{out}). Average temperatures are those when people in that climate feel comfortable. The adaptive opportunities allow the neutral zone to be extended. It is also partly an attribute of the building together with the social conditions in the buildings.

However, sometimes the differences in thermal sensation votes between climate chambers and the real fields can not be accounted for by inaccuracies in measuring clothing and activity. If so, then maybe there are genuine context effects, which could be due to the physical properties of the environment (e.g. decoration and furnishings), or to more social factors such as the attitude the occupants have to the level of comfort in that environment and the expectations. In simple deterministic terms the environment affects a person's sensation of that environment which in turn alters their perception and finally their assessment using a rating scale. Current standards, e.g. ISO, CIBSE and ASHRAE, all recommend different design temperatures for the same environments. In fact, ISO7730 and ASHRAE 55 consider thermal comfort without regard for other requirements such as light, noise and indoor quality. The question is 'should the interaction of requirements be considered in standards?

Nevertheless, the general finding is that the PMV can be a poor predictor of actual votes and of satisfaction with the thermal environment. This may be for several possible reasons that have been mentioned by Raw et al (1994: p4-5):

a) the predictor variables are not adequately measured;
b) the equation does not take into account the 6 main variables correctly;
c) other physical variables are important; and
d) people adapt by changing the physical parameters (environment), their physiology or activity level, their expectations, and the way they use rating scales.

Consequently, Raw et al (1994) states also that "In simple deterministic terms the environment affect a person's sensation of that environment which in turn alters their perception and finally their assessment using a rating scale. However, this simple representation of the effect of the environment does not consider complications such as the indirect effect of physiology on perception nor the direct effect of context and culture", as illustrated in Figure 3.12 below.

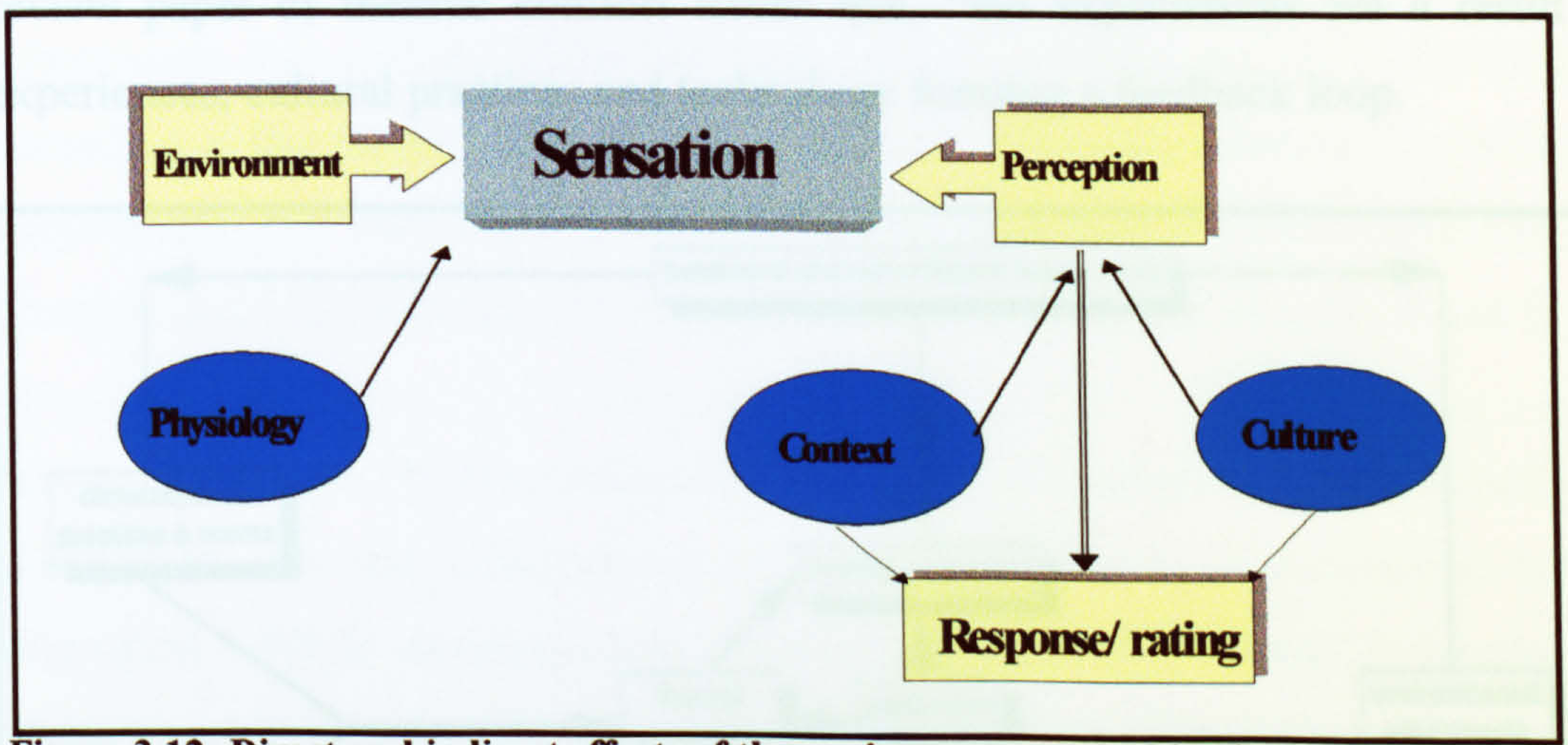


Figure 3.12: Direct and indirect effects of the environments on subjective ratings. Source: Raw et al (1994: 5).

Many researchers have identified this issue, and they recommended that it needs further observation. For instance, Heijs (1994) points out that the terms 'thermal sensation' and 'thermal comfort' are used as though their meanings are the same. He states that cognitive psychologists distinguish between the processes of sensation, cognition and evaluation. In addition to that, he explains that ratings of thermal sensation and comfort show significant differences in interpersonal variation.

Nevertheless, the psychological issue of comfort, in thermal comfort studies, is rarely discussed and the research concentrates on the relationship between ratings of thermal sensation and temperature. In order to emphasise the importance of what mentioned above, if the hypothesis of the adaptive model analysis well same as the explanation of de Dear (1994). He states that:

> "adaptation hypothesis indicates that one's satisfaction with an indoor climate is achieved by a correct matching between the actual thermal environmental conditions prevailing at that point in time, and one's thermal expectations of what the indoor climate should be like at that same point in time".

His illustration of the adaptational model (as shown in Figure 3.13), bears an uncanny resemblance to Oseland's (1992) model of space satisfaction, which was developed independently of the thermal model. Oseland, like de Dear, places emphasis on expectations and past experiences, but also distinguishes between the physical and psychological aspects of the environment. Furthermore, Oseland (1994) states, in his review paper of thermal comfort issues that, "the expectations are a result of past experiences, cultural practices and technology forming a feedback loop.

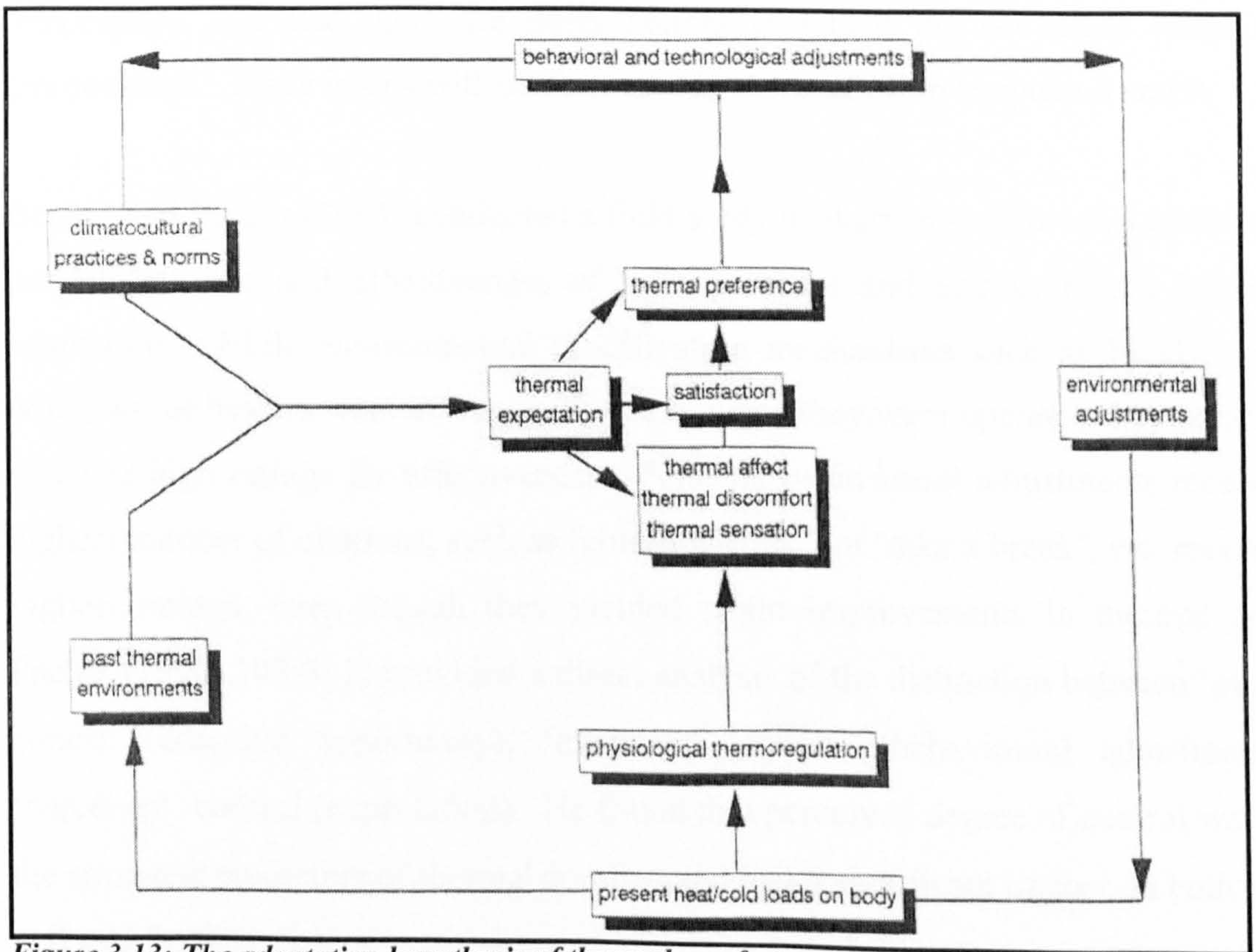


Figure 3.13: The adaptation hypothesis of thermal comfort.
Source; de Dear (1994: p 107).

In practice, the adaptational model is derived from a regression of neutral temperatures by mean indoor and outdoor temperatures obtained from world-wide filed study data, as mentioned earlier. In contrast, the PMV model denies any form of adaptation". However, the adaptation or feedback model has evolved from empirical field research conducted throughout the world (Humphreys, 1994). Acclimatisation consists of a series of physiological adjustments that occur in a person who is habitually exposed to either the hot or the cold condition. As a general phenomenon, the interaction of moisture, air and heat influences our sensation of thermal conditions. Therefore, in a hot climate, physiological adaptations occur which help to cool the body. In a hot-dry climate, where there is very low moisture and the air speed is very low, some processes will increase such as sweating, blood volume and water intake. As well as behavioural changes, other changes occur: less clothing is worn, or heat is avoided e.g. resorting to an air-conditioned room.

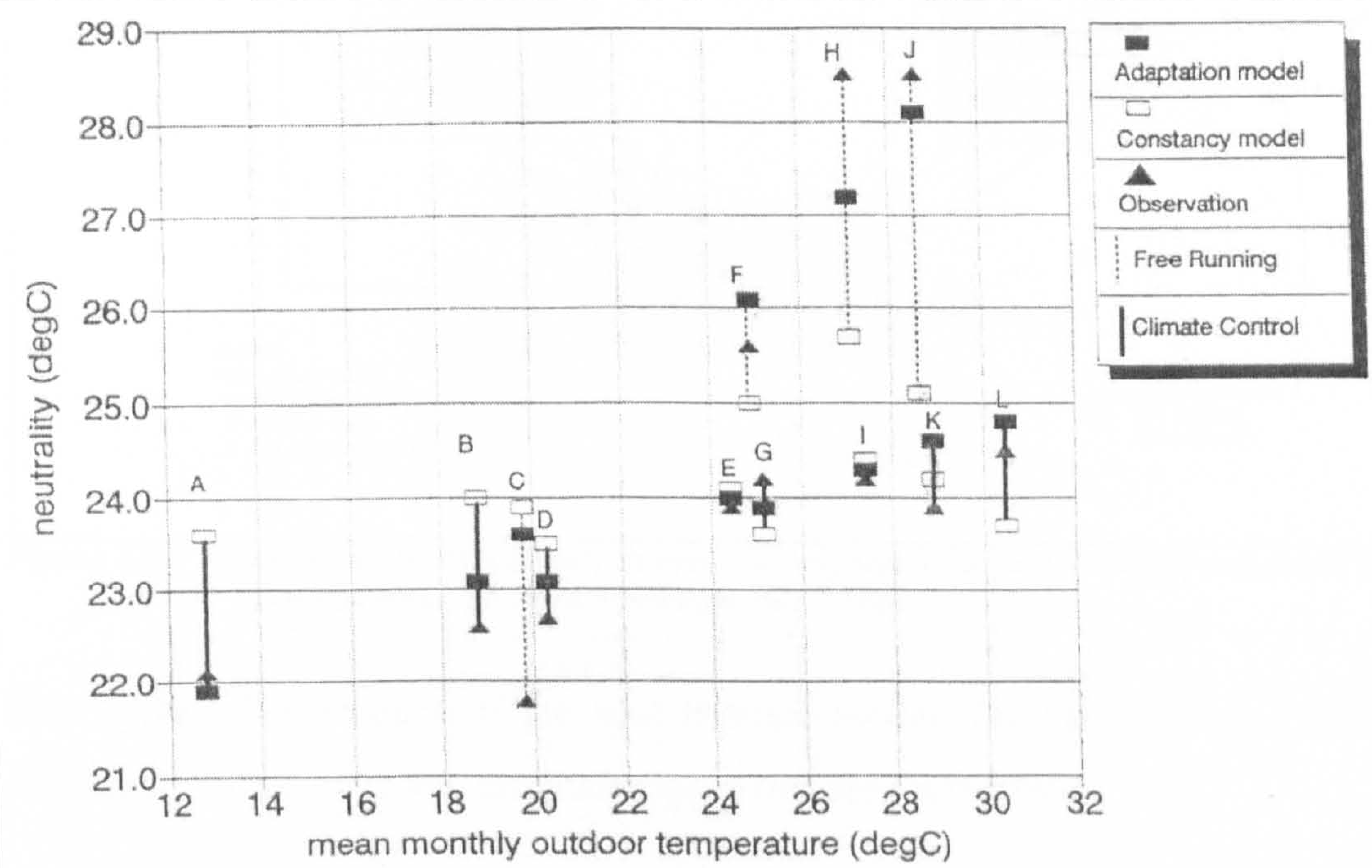
Thus the dependence of indoor neutrality on outdoor climate may be due to behavioural adjustments that directly affect the heat balance. Might not only changing clothes according to the season could lead to these behavioural adjustments to a wide range of temperature, but also there are other factors in which the occupants adapt to the environment. These issues will be discussed in more detail in chapters 8 and 9.

Benton and Brager (1994) conducted a field study of thermal comfort that addressed the availability, use and effectiveness of both personal and environmental behavioural adaptation. While environmental modification mechanisms such as blinds, operable windows, or heaters were in frequently cited, when they were operated they consistently received high ratings for effectiveness. Personal behavioural adjustments received the highest number of citations, such as 'cold/hot drink', or 'take a break', etc. received the highest ratings, even though they yielded slight improvements in thermal comfort. Paciuk (1990: 303-312) provided a direct analysis of the distinction between 'available' control (adaptive opportunity), 'exercised' control (behavioural adjustment) and 'perceived' control (expectation). He found that perceived degree of control was one of the strongest predictors of thermal comfort and had a significant impact on both comfort and satisfaction.

However, psychological adaptation refers to an altered perception of, or response to, the thermal environment, resulting from one's thermal experiences and expectations. The role of personal control has been frequently cited as a key factor influencing this adaptive mechanism. The role of personal control on thermal and expectation response has important implications in naturally ventilated vs. air-conditioned buildings. The adaptive hypothesis implies that if occupants in a centrally controlled building have generally experienced fairly constant and uniform conditions, with limited opportunities for personal control, then they not unreasonably expect their building to automatically provide them with perfect comfort. Then when it fails to meet those expectations, they will be more likely to judge that building harshly compared to a situation were they had control over those conditions. Paciuk ((1990) presents that personal or environmental adjustments in air-conditioned buildings actually had a small negative effect on satisfaction.

Furthermore, Gagge and Nevins (1976) and Elder and Tibbott (1981) both found very widespread thermal dissatisfaction among the occupants of North American air-conditioned office buildings that were subjected to set-point adjustments of only a few degrees. Some researcher have looked at studies in air-conditioned buildings and naturally ventilated buildings, like Raw et al (1994: p59-69), both with and without supplementary on-demand cooling and heating equipment. They found a significantly higher level of satisfaction in the naturally ventilated buildings with additional supplementary control. Therefore they concluded that people have a wider tolerance of variations in indoor thermal conditions if they can exert some control over them. Ealiwa et al (1999: p 166-171) have found similar patterns in a thermal comfort field study in Ghadames, and neutrality was much lower than predicted by PMV, especially in the naturally ventilated buildings (old).

de Dear (1994, 1995) extended his analysis to include the work of Busch (1990) in Thailand and the work of Brager (formerly Schiller, 1990) in America in addition to his own work in Australia and Singapore (de Dear et al, 1991). He re-analysed the data set, and he found that the neutral temperature (t_n) computed from the PMV was only a better predictor than the adaptive model in one building but equally as good as adaptive model in three, as shows in Figure 3.14. Oseland (1994: p45-54) who conducted a large number of field studies in UK in different buildings and, using a variety of methods, found that thermal neutrality and preferences were significantly lower in the homes compared to the offices. The differences could not be accounted for by changes in clothing, activity, or air velocity. All of these patterns support the notion that people grow to accept the thermal conditions to which they become accustomed Humphreys (1981: 229-250). Cena et al (1986: 329-342) have mentioned that this acceptance might be influenced by factors such as personal control, consumption of energy, or concern for the environment and the associated societal pressures to conserve energy.



Code	Location & season	Climate Controlled or Free Running	Author
A	San Francisco-winter	CC	Schiller et al (1988)
B	San Francisco-summer	CC	Schiller et al (1988)
C	Melbourne-summer	FR	de Dear + Auliciems (1985)
D	Melbourne-summer	CC	de Dear + Auliciems (1985)
E	Brisbane-summer	CC	de Dear + Auliciems (1985)
F	Brisbane-summer	FR	de Dear + Auliciems (1985)
G	Darwin - Dry	CC	de Dear + Auliciems (1985)
H	Singapore	FR	de Dear et al (1991)
I	Singapore	CC	de Dear et al (1991)
J	Bangkok	FR	Busch (1990)
K	Darwin-Wet	CC	de Dear + Auliciems (1985)
L	Bangkok	CC	Busch (1990)

Figure 3.14: Thermal Comfort Experiments in the Field: Observed and Predicted Neutralities in Relation to Outdoor Climate. Source: de Dear (1994: 115).

The ideas of the adaptive opportunities allowing the neutral zone to be extended, is due to partly an attribute of the building and partly of the social conditions in the building. Furthermore, Baker and Standeven (1994), concluded their paper with a new approach, which was based on the assessment of both adaptive opportunity and thermal satisfaction, as shown in Figure 3.15. This approach provides a basis for responding to climate, a global building thermal characteristic, and adaptive opportunities, rather than predicted temperature.

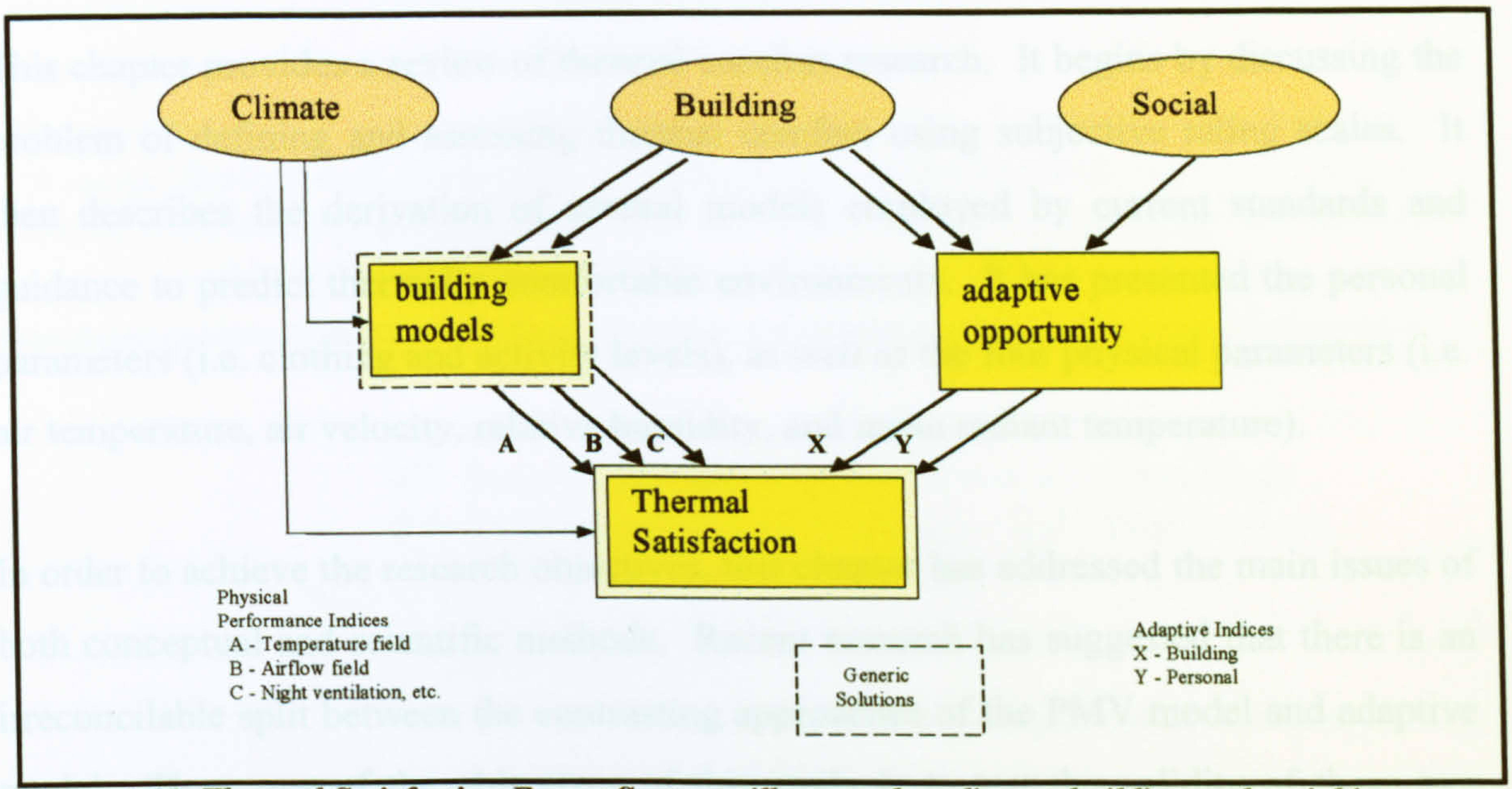


Figure 3.15: Thermal Satisfaction Expert System will respond to climate, building and social inputs. Source: Baker, N. and Standeven, M. (1994).

Thus, given that account of the heat balance model, for the effects of behavioural adjustments to be included, the challenge in this area is twofold:

a) When the model is used to predict thermal conditions resulting from design decisions, one needs to carefully estimate what the anticipated clothing and activity levels will be, and how occupants will use the local environmental controls, which will affect the indoor thermal environment.

b) When using the model to assess existing thermal comfort conditions, it is critical that field methods accurately measure thermal conditions directly at the occupant's location in space and time and that careful assessments are made of activity and clothing levels, including the effect of the chair.

In the first point that is possibly where an adaptive model could make an important contribution by taking account of the feedback loop between dis-comfort and purposive behavioural thermo-regulation. In some cases, this would eliminate the need to guess what the clothing patterns of future, unknown occupants might be.

3.5 Summary

This chapter provides a review of thermal comfort research. It begins by discussing the problem of defining and assessing thermal comfort using subjective rating scales. It then describes the derivation of several models employed by current standards and guidance to predict thermally comfortable environments. It has presented the personal parameters (i.e. clothing and activity levels), as well as the four physical parameters (i.e. air temperature, air velocity, relative humidity, and mean radiant temperature).

In order to achieve the research objectives, this chapter has addressed the main issues of both conceptual and scientific methods. Recent research has suggested that there is an irreconcilable split between the contrasting approaches of the PMV model and adaptive model. Thus, one of the objectives of this study is to test the validity of these two models (i.e. PMV and adaptive) in such hot-dry environment, as mentioned in chapter one. This objective has been addressed because of the arguments of some discrepancies between climate chambers and field surveys.

The chapter ends by highlighting hypotheses relating to these two models as shown by the findings of the literature review. They in turn have influenced the form of the model presented in this thesis especially in chapter 9 (section 9.2).

The information associated with the methodology of this research work is described in chapters 4, 5 and 6, in order to achieve the main objectives that have been mentioned in chapter 1.

Chapter Four:

FIELD SURVEY; Research Methodology

"Research is used to mean many different kinds of things. Generally, it is used simply to mean '***finding out***' something. ... In each case, of the research, we would have to decide what information is needed, how can it be collected, what factors are relevant and how the information can be used". Allison, Brian (1998: p5).

4.1 Introduction

A field survey is a key part of understanding the true nature of people's interaction with their environment. This research is concerned with the conduct of field surveys and the analysis of the results, in order to measure human thermal comfort and to test the validity of two comfort indices, namely predicted mean vote model (PMV) and the adaptive model, in a hot-dry climate. Allison (1998) states that "... professional research is characterised by being rigorous and systematic, is pursued through the use of appropriate research methods and invariably culminates in a report of some kind, which also needs to conform to accepted standards". Furthermore, he mentions that research is a systematic enquiry, which is reported in a form that allows the research methods and the outcomes to be accessible to others, and adds that research is concerned with seeking solutions to problems. These characteristics are embodied in the following sections.

In this chapter, details of the method used in the study and the reasons for choosing it are discussed. The chapter begins with a discussion of the reasons for choosing Ghadames as a case study. There follows, a description of the technical considerations, which have been explored for this research. The subjective-study is then considered, including the criteria behind the design of the questionnaire, site selection, and other considerations. Next, the objective-study is described including of the instruments that have been used, site selection, and the experiment scope and plan. Finally, the sequence of the experimental procedures is presented so that the whole framework of the research can be visualised clearly.

4.2 Reasons for Choice of Ghadames as a Case Study

The Ghadames Oasis region is climatically and architecturally typical of Libyan specifically, and of Northern African areas generally. The Ghadames oasis has two types of buildings, which are;

a) Traditional old buildings that employed natural ventilated system (NV), and
b) New contemporary buildings that employed air-conditioned system (AC).

Individually these two types of buildings are flats or one or two storeys high, which are constructed either by private sector or public sector. The general purpose for selecting the Ghadames area as a case study is to identify and uncover typical problems pertaining to current efforts with regard to thermal comfort and the indoor environment for that region which has a typical hot-dry climate. Therefore, the following points address the main reasons for choosing that particular area to conduct this survey: -

1. Primarily, both building types exist and are still occupied. Ghadames represents a unique traditional human settlement, fortified by a wall and consisting of about 2,120 old building units, with other public activities. Also, it represents a clear expression of both traditional and modern attitude that each society would held. This permits both objective and subjective measurements to be made.

2. Secondly, its location, is crucial - since it is part of a trade route connecting central Africa with the northern part at the Mediterranean Sea coast. This fact made the Libyan Government give much attention to Ghadames oasis, and rank it as one of the most important cities in the country.

3. Finally, the old town of Ghadames has been added to the UNESCO World Heritage conservation list. It was also listed as a historical monument in 1987. Other workers have obtained much domestic socio-economic information in this region (see chapters 2 and 5).

All of these points provided the main reason for choosing Ghadames as a case study for this research in order to explain current and prevailing conditions of indoor environment in terms of thermal comfort. It provides a clear chronological section investigating the interaction of human beings *(occupants)* inside each type of building and their responses in terms of thermal comfort issues.

4.3 Exploring Research Techniques and Considerations

This research project deals with investigations of thermal comfort issues in real existing buildings and considers principles of human behaviour. It reflects different standpoints principally based on positive facts and observable phenomena that represent fundamentally the real life of people *(occupants)* who are struggling against an extreme and severe harsh hot-dry climate. Despite these conditions, which cause them some difficulties of life, they adapt themselves to live in such environment.

on the indoor climate and human behaviour. It aims also to compare the thermal comfort level in each type of building with the other, and examine the validity of the two world wide thermal comfort models (i.e. PMV and Adaptive).

This enables a comparative study of thermal comfort issues with regard to traditional architectural design form that is naturally ventilated compared with the modern architectural design form that is air-conditioned. This in turn, would identify which types of design form successfully meet or achieve their occupant's satisfaction requirements with their built environment as well as their thermal comfort level. It would also establish coherent characteristics of appropriate building design form in Ghadames region or to any other regions that have the same type of climate. The clarity and accuracy of the data and results strongly and significantly influence the usefulness of this kind of field surveys.

4.3.1 Preparation

It has been decided to conduct this survey in Ghadames Oasis as a case study for this research to represent a typical hot-dry climate area in North Africa. The first thing in order to conduct a field survey to any researcher is that he/she should have a clear idea of the area of the case, must know what is needed to measure, and how he/she intends to measure it. The questions asked through the questionnaire were related directly to the occupants in order to understand their opinion about their building design, their daily activities or behaviour, their control over openings like windows, and the indoor environment in terms of the thermal comfort.

The survey aimed collecting as much information and data as possible through four main resources:

a) Participants by using questionnaire (i.e. subjective study), to be distributed among 30 traditional NV buildings in the old town, and another 30 contemporary AC buildings in the new buildings. This represents a total of 270 subjects (i.e. 135 person in each type of building).

b) Field observation by the Author during the field survey in summer 1997.

The field survey is concerned with human behaviour in existing constructed buildings. It reflects some degree of uniformity, but not at the same level of control as chamber or laboratory studies. For example, the occupants vote in the questionnaires, such as the 7-point sensation scale, or the 3-point preference scale, or the 2-point satisfaction scale, will be subjective to some extent, and not wholly precise. These scales might be understood differently by one person to another and, in particular, when they are translated from English to Arabic, they might not give the same meaning, etc requiring care in the translation.

The ultimate aim of the research is to test the applicability of the PMV and the Adaptive thermal comfort models within two types of buildings; traditional naturally ventilated buildings and modern air-conditioned buildings. Also, it aims to conduct a subjective survey in order to measure the response values of occupants in each type of building individually, and examine their thermal satisfaction by distributing specific designed questionnaires among the people of Ghadames region. The background of building design in Libya generally and in Ghadames specifically, together with the literature review of the thermal comfort field survey studies suggested that five main groups of data needed to be obtained from the people, to conduct the subjective study:

1- Social aspects of human behaviour in Ghadames old and new towns (human interaction with the environment), such as; religion, life style, working patterns, clothing, and diet and activities.
2- General view and future wellbeing of the residents at each town.
3- Thermal preference vote.
4- Thermal sensation and comfort votes.
5- Thermal satisfaction vote.

In addition to the above five categories, at the same time and in the same place, the empirical survey is should also included into the objective study in order to assess thermal comfort by measuring six basic parameters, namely; air temperature, air speed, mean radiant temperature, relative humidity, thermal clothing resistance and metabolic rate. The objective of this investigation was to establish a set of relationships between the outdoor climate, which we as human being do not have any control over, and the indoor climate, which we can control in order to achieve our thermal comfort requirement level. The investigation aims to evaluate the effect of the outdoor climate

c) Interviewing Local Authority officers of Ghadames by the Author during the field survey in summer 1997.

d) Physical measurements (i.e. objective study) in 9 traditional buildings, and 10 contemporary buildings. This represents 85 subjects, i.e. 40 person in NV and 45 person in AC buildings.

Sarantakos (1996: p.177) states that "Interviews are often the decision-makers as a standard method of data collection in most researching design, irrespective of the underlying methodology. The degree to which interviews are structured depends on the research topic and purpose, resources methodologies standard and preferences and type of information sought, determined by the research objective". Furthermore, Herbert (1990: p.53) has mentioned that "interviews are used to find out not only what happened to the client, but also his or her perception of the events – the meaning ascribed to them and the current evaluation put upon them". Therefore, it was very important for this field survey to do some interviewing and observation by the Author in order to uncover relevant information and direct verbal interaction between individuals, where the opportunity for asking questions is extensive and the rate of return is good. For example, the interviews of the local authority officers uncovered the reason for the indoor conditions and control actions over the buildings by the occupants to prevent over heating, supporting the appropriateness of this research method.

Both areas of the old and new town of Ghadames have been reviewed in order to get a clear overview of the Ghadamesian way of life in such region. Interviews with the local Authority in Ghadames have been made, in order to gain their information relevant to interpreting the subjective measurement data, and making recommendations. For example, whether if they consulted the local people of Ghadames before moved them from their old town to the new one; and whether if they took into consideration socio-cultural aspects or requirements of the people when they design the new town, etc. They were senior government management officials from Municipality of Culture and Art Tourism, Department of Planning and Housing, and Local Municipality of Utilities. Due to the limited time factor, an observation was also held by the Author himself during the field work period.

4.3.2 Considerations

Further points have been considered before and during the field-work. Firstly, due to power of computers these days, especially in conjunction with automatic data-loggers, there is a temptation to move directly to sophisticate statistical techniques. Such techniques however are clearly taken as key tools now days. The more accurate measuring instruments and associated analysis software could give an illusion of complete objectivity, where as the data required careful interpretation.

The second consideration is the choosing of the people who are involved as subjects, and the design of the experimental work. There was a very specific programme with timing designed especially for this type of survey. The case study in Libya is located far away from the place of the research in England. Therefore, it was necessary to make the most of the opportunity available to obtain information about the people and their life in such an environment, since it was likely there would not be another opportunity to do so.

The third consideration is the method that has been used to draw conclusions from this kind of survey. Finally, there are very important facts that must be considered when dealing directly with ordinary Ghadamesian people. The religion and culture of the people, such as the segregation between male and female, become very important and crucial issues. Also the scientific questionnaire itself needs to be used carefully after translation into Arabic, as it has been realised that it is not easy to understand the exact meaning of each question (e.g. the 7-point sensation scale, preference scale, etc.).

All of these issues still need more explanation to avoid any misunderstanding or delay. Therefore, it was decided to divide the participants from the 60-buildings (i.e. 270 person) into small groups, meet each group individually and explain to them in detail each section in the questionnaire and how they should fill in their votes, etc. To do this in addition to the objective survey in a very short time, and by one person, was a very hard job.

4.4 Subjective Study

Subjective data were collected from subjects by using questionnaires distributed among the randomly chosen residents who were taking part in the survey (from 135 subjects in the 30 old and 135 subjects in the 30 new buildings). The aim was to assess their actual mean vote (AMV) on the 7-point ASHRAE sensation scale and 4-point comfort scale together with normal questions about their well-being and behaviour. For more details please see Appendices A and B. Representative buildings from Ghadames residential building stock were selected for subjective measurement (30 old and 30 new buildings) with an average occupancy 4.5 person/building. Therefore;

1) The number of buildings (i.e. 30 old and 30 new sampling for this field study) was significant compared to total number of building stock in Ghadames (1.4%). It was slightly above the minimum recommended number by most researchers in order to be sufficient for conducting a field survey (i.e. 25 buildings for each type).
2) The sample size of both buildings and participants adopted in this work was necessarily limited due to shortage of time and measurement instruments, as outlined before in section 1.3.3.
3) The subjective measurements represented approximately 270 participants (about 1.4% of the total population of Ghadames).

4.4.1 Criteria Behind Designing of Questionnaire

The closed questions were intended to find out the attitudinal, as well as the factual, data from the respondent while the comments at the end of each section of the questionnaire for each type of building, gave the respondent the freedom to response spontaneously (Oppenheim, 1996: pp 112-113). The questions asked were related to the occupants' opinion to evaluate the thermal performance level for each type of their building individually. There were other sections in the questionnaire in which they described their daily activities and way of life, and evaluated the indoor environment level of their buildings (see Appendices A and B). These data complemented the data on their social requirements and personal acclimatisation, in order to be used as main resources for chapters 7, 8 and 9. The questionnaire that has been used is well known and has been approved by many researchers in the thermal comfort fields. The total number of questionnaires handled, distributed randomly among 60 buildings, which represented 270 person, based on the average family size (4.5). There was a 100% response to the questionnaire. For more details, see chapters 6 and 7.

Subjects from 19 buildings (9 old, 10 new)were asked to complete a questionnaire at the same time as the environmental variables (air temperature, globe temperature, surface temperature, air velocity and relative humidity) were being recorded. Details of clothing and activities were noted for each subject. The subjective study involved collecting data using questionnaires. The questionnaire was based on 6 sections: - background and personal information; social interaction; thermal environment and personal influences; occupants' perceptions of the environmental conditions in the whole building; occupants' thermal comfort; people's general feeling and personal well being. The full questionnaire is presented in Appendix A.

For the purpose of this research, only the personal information and occupants' thermal sensation data have been presented including data about the age and gender of the subjects and his/her family: how many hours/day are spent inside the building including sleeping time; is there air-conditioning units; etc. The occupants' thermal comfort has been tested using a 4-point scale for thermal comfort, dryness, stickiness and draughtiness scales, while 7-point sensation, preference and satisfaction scales have been used. The questionnaire has been translated into the Arabic language (see Appendix B) and distributed among the residents in Ghadames oasis. The subjects were selected randomly from different groups of people in Ghadames (i.e. Educated, Administrative, Architects and Elite groups) to represent typical range of samples. Care was taken to minimise the risks of mis-understandings arising from translations of the words describing the points on the various scales by interviewing the respondents and assisting them with completion of the questionnaires.

However, more explanation regarding the field survey procedure (subjective and objective surveys) would included in chapter 6, such as selection of subjects and buildings, instrumentation, field survey strategy, etc. There should be two questionnaires:

a) one for 60 buildings (overall and general sensation); and
b) out of these total buildings, there would be extra questions for 19 buildings (current sensation, when measurements were taken).

4.4.2 Site Selection

These participants were randomly selected, but consideration was given to confine small samples in each zone within the old town and the new town of Ghadames. Therefore, each area divided into six zones, where in each zone only 5 buildings were chosen to fill the questionnaires (representing about 23 person in each zone). This strategy was adopted equally among the residents of both old and new towns in Ghadames. The interviewing method with the Local Authority officials in Ghadames, as well as some residents from each town, was conducted by the Author himself during the field survey work. Also, the Author observed the site of each town, such as their building conditions, their planning, and the daily life activities of the residents. For further details, see chapter six (section 6.2).

4.5 Objective Study

4.5.1 Method

At the same time as when the subjective reactions were taken, the six basic environmental parameters were measured in 19 buildings. The purpose was generally to test the validity of both Fanger's PMV and adaptive models in such hot/dry climate. Because the aim was to obtain a typical reaction to conditions there was no attempt to interfere with normal conditions or modes of dress, so the full complexity of the situation was included in the responses of the subjects.

Figure 4.1 shows the method which was used to predict the thermal comfort using both the PMV and the adaptive models among two types of buildings; 9 old buildings that employ natural ventilation systems with courtyards and 10 new buildings that employ mechanical ventilation systems. There were seven stages to achieve the final results, which helped to draw the conclusions determining whether there would be any significant differences between these two types of buildings in such an environment as Ghadames. Furthermore, the results were used to test the application of the PMV and the adaptive thermal comfort models in hot-dry climate.

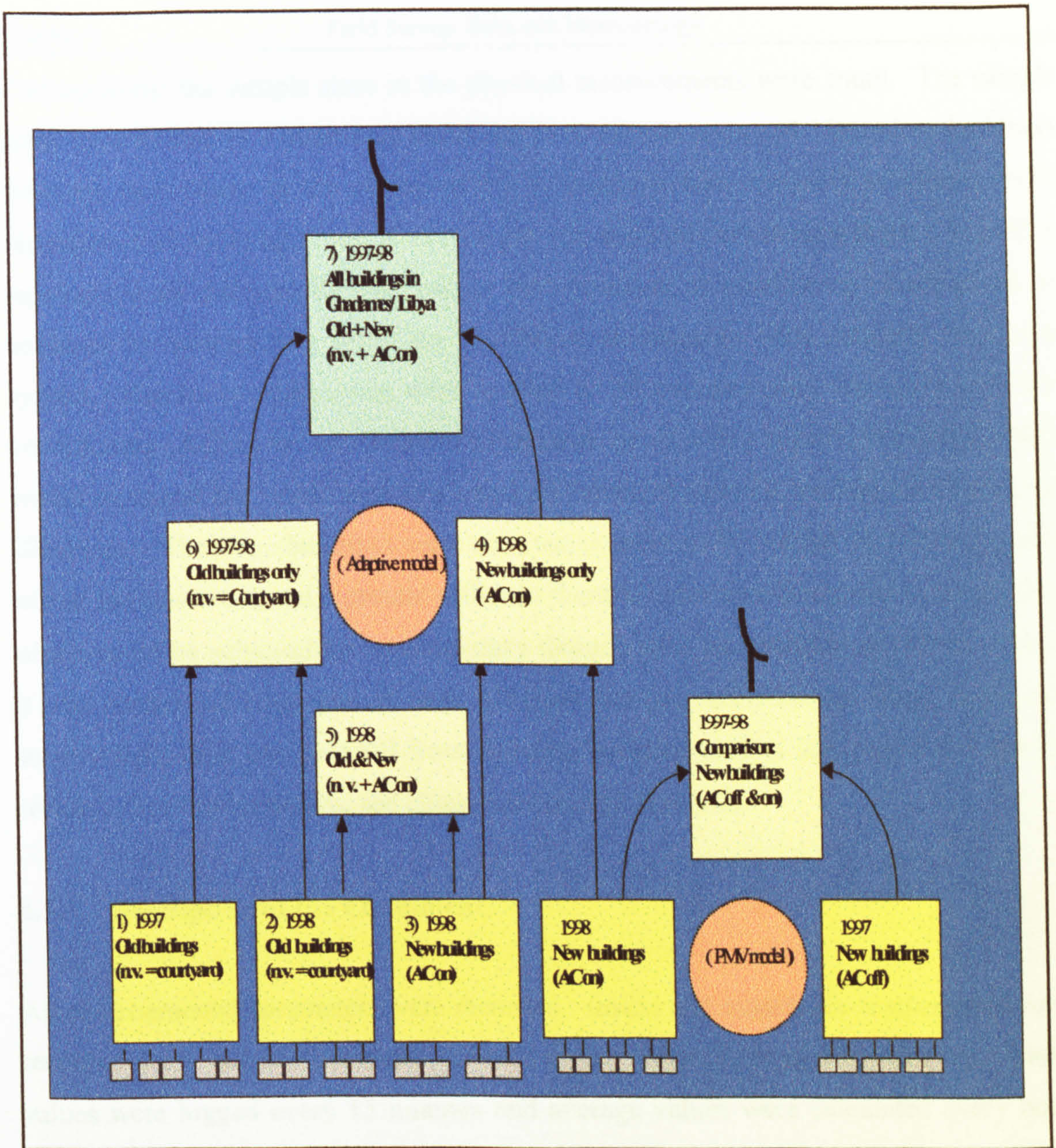


Figure 4.1: Schematic representation of the survey method to validate both the PMV and adaptive model in Ghadames oasis, 1997-98. (Note; n.v. =natural ventilation, AC. = air-conditioning).

4.5.2 Site Selection

It is very difficult to find people who agree to participate and allow any researcher to conduct his physical measurements using instruments inside their building for 24 hours to assess the PMV model. It is even more difficult to find a person who would allow for the researcher to use their building for one week to assess the adaptive model. These strategy for this field survey has been taken due to the limitation as mentioned before in chapter 1 (section 1.3.3).

Consequently, the sample sizes in the physical measurements were small. The sample sizes were limited to 9 traditional buildings from the old town and 10 modern buildings from the new town. In the old town the 9 buildings with naturally ventilated (NV) represented all building types, if there were any differences between them. Also they represented all different thermal indoor environments or conditions, which could be achieved by constructing using the traditional architecture with naturally ventilated system. Similar considerations were applied to 10 contemporary buildings with air-conditioning (AC) in the new town of Ghadames by selecting specific buildings, which would represent the whole new town and all forms of existing modern architecture in Ghadames. These ten buildings were selected in order to be located in different places within the new town, and represent different thermal indoor environments or conditions, which could be achieved by contemporary designs with air-conditioned system. Thus, it was considered important to have different designs, such as one storey high, two storeys high, flats, etc. selected from different building sectors (i.e. public and private sectors). For further details, see chapter six (see section 6.2).

4.5.3 Description of the Equipment

All environmental parameters were recorded. Inside and outside air temperatures were recorded using radiation-shielded thermocouples (Type T, copper/constantan). These values were logged every 15 minutes and average values were calculated every hour. Indoor air speeds were measured using an omni-directional anemometer. A wet and dry bulb thermometer was employed along with a 46mm globe thermometer for measuring the mean globe temperatures; mean radiant temperatures were then calculated. The equipment used in this study complied with the criteria given in ISO 7726 standard (1994). From the reading of these instruments together with the estimation of personal factors, the current thermal comfort indices can be tested. Subjects completed a questionnaire at the same time as the measurements were taken at the end of each two-hour session. This thermal comfort questionnaire included a 7-point ASHRAE thermal sensation scale, from which the actual mean votes (AMV) of the subjects were determined.

4.5.4 Experiment Strategy

Different techniques were employed as appropriate in this experimental work relating to thermal comfort issues among two different types of existed architecture design buildings in such an environment.

4.5.4.1 Experiment Scope

In the empirical field survey the method was to ask subjects taking part in the survey to assess their thermal sensation on a subjective scale running from 'cold' to 'hot', which is known as the 'Thermal Sensation Vote'. At the same time when the subjective reactions were taken, the environmental variables were measured. The interest was generally in finding a temperature or range of temperatures, and other environmental variables, which people at that locality would find comfortable. Because the aim was to obtain a typical reaction to conditions there was no attempt to interfere with normal conditions or modes of dress, so that the full complexity of the situation was included in the responses of the subjects. The aim was to perform a multiple regression analysis of human sensation votes as a dependent variable against the independent variables of the physical environment (i.e. AMV vs. PMV and t_n values). The underlying assumption of the field survey was that people are able to act as meters of their environment. This assumption was rooted in the findings of psychophysics.

In effect the subject is used as a comfort meter, not of temperature alone but of all the environmental and social variables simultaneously. (Nicol, 1993: 14-15). All prospective subjects were given an explanation of the procedure in writing, and verbally where requested. Before the start of each experimental session, all subjects completed a medical form and a consent form. See Appedices A and B. The procedure was given ethical clearance by Sabha University in Libya together with De Montfort University in the UK in August 1997.

4.5.4.2 Experimental Plan

As a consequence, 19 buildings were selected to represent typical buildings. Eighty-eight subjects (ages between 20 and 50) were recruited during the project, together with two assistants who helped in dealing with preparation of the monitoring procedure. Subjects were asked to carry out their typical activities for a period of two hours at three different sessions during the day of experimentation, from 8am to 10pm. The three sessions were selected at 10am, 2pm and 8pm, with subjects completely relaxed and carrying out their normal lightly active every day life of the population in Ghadames. A questionnaire was completed at the end of each session. All environmental parameters including the outside air temperature were recorded for one week for each building (20-26 July 1998). The main body of the data was collected during the hot time of the day; the overall average outside air temperature of the observations was therefore substantially higher than the mean indoor air temperature of the buildings.

4.6 Summary

In order to understand the methodology that has been used in the research, this chapter has highlighted the model of the method which was planned to predict the thermal comfort using both the PMV and adaptive models among two types of buildings. In this chapter, detailes of the reasons for choosing Ghadames as a case study have been explained, then described the technique that had been explored for this research. It also included the criteria behind the design of the questionnaire. After that, it has described the instruments that have been used, and the site selection for both subjective and objective studies. Finally, it has presented the sequence of the experimental procedures in order to visualise the whole framework of the research project. These details have been highlighted in this chapter in order to present in a clear way the link between the previous chapters and the chapters five, six and seven. In these chapters where some background issues are highlighted about case study area as related to the research topic, and the collected data are addressed to start analysis.

Chapter Five:

GHADAMES CASE STUDY: Background

"Man, it seems, has forgotten how to design with keeping in mind the climate and tends to ignore it while he has become preoccupied with forms, currently fashionable. The modern building – office or dwelling – looks much the same the world over, because, among other things, it has been designed largely to keep natural phenomena outside, to separate conditions inside from the outdoors much as possible, relying on mechanical devices and systems to do much of the work". (Konya, 1980).

5.1 Introduction

The towns and oasis settlements located in the desert of Libya are mainly traditional settlements, whose economies have developed rapidly since the discovery of the oil, i.e. Ghadames, Murzuk and Ghat. These developments however have great implications on the built environment in these settlements, of which Ghadames oasis is a good example. Ghadames can be taken as a good example of this development in the building sector, because both traditional buildings and contemporary buildings still exist and are occupied.

People who came either to work or to visit 'Libyan Jamahiriya' generally or 'Ghadames oasis' specifically stated that "As the pearls imprison the languid light stolen from the moonbeams reflected on the waters of the sea, so does Ghadames. Thus, to enter Ghadames, is to enter such an inconceivable reality as to seem spellbound; it's a dream-world that the desert preserves and protects in its embrace, revealing its precious contents only to those who can observe with their heart".

This chapter aims to address firstly the general aspects of Ghadames oasis, such as its historical background, population and economic aspects, social and cultural way of life, and climatic characteristics. Secondly, it highlights the townscape features of both the old and the new town of Ghadames (i.e. its layout, building form, and building method and materials). The study of architecture in Ghadames is useful, in order to give a general idea of the evaluation of the case study environment and the response of the occupants to the environmental conditions they are living within, together with their socio-cultural requirements which determined certain architectural forms and characteristics. This information will be used to identify the suitability of the case study in measuring the satisfaction of the occupants who are involved in this field study with their built environment in both the traditional and contemporary buildings, in terms of their thermal comfort levels.

5.2 Characteristics of Ghadames

5.2.1 Ghadames Location and its Natural Features

Ghadames is located in the south-west of the Sahara desert of Libya, which lies 630 km south-west of Tripoli, situated at an altitude of 350 meters above sea level, and close to the junction with the borders of Tunisia and Algeria. It also forms a part of the sub region of Gharyan, which is one of five sub regions of the Tripoli region. See Figure (5.1). The geographical co-ordinates of the city are at 30° N latitude and 9.6° E longitude. It is on a very important trade route connecting central Africa with the northern area of Libya at the Mediterranean Sea coast. Furthermore, the UNESCO has added Ghadames to the World Heritage list of historic monuments in 1987. No doubt these facts make the Libyan Government give good attention to Ghadames oasis, and rank it to be one of the important cities in the country. All of these points and others, which have been mentioned earlier in chapter four, section 4.1, make Ghadames an appropriate location for the case study of this research. Since, this research is focused to study the thermal comfort issues which based on field survey method in order to compare two different types of buildings (NV and AC) where they both are existing at the same environment and still been occupied.

The Ghadames area lies within the borders of the Al-Hamadah Al-Hamra. Polservice (1980) has stated that the oasis lies in a depression surrounded by a salt marsh, and it is shielded on the eastern side by rocky outcrops covered by sand, and on the western side by a crescent shaped range of sand hills. The Ghadames soil is clay and stone, which is not suitable for agricultural use, so the people import their food from other areas. The land is covered with weathered bedrock or dust and sand sediments of fluviaeolian origin. In spite of that, they have made use of existing local materials, such as palm trunks, clay and stones (i.e. limestone, gypsum, etc.) to construct their old town buildings. The old town was originally protected from the drifting sand and from the high air temperature of the surrounding desert by palm trees and currently 36,000 palm trees predominate in the oasis.

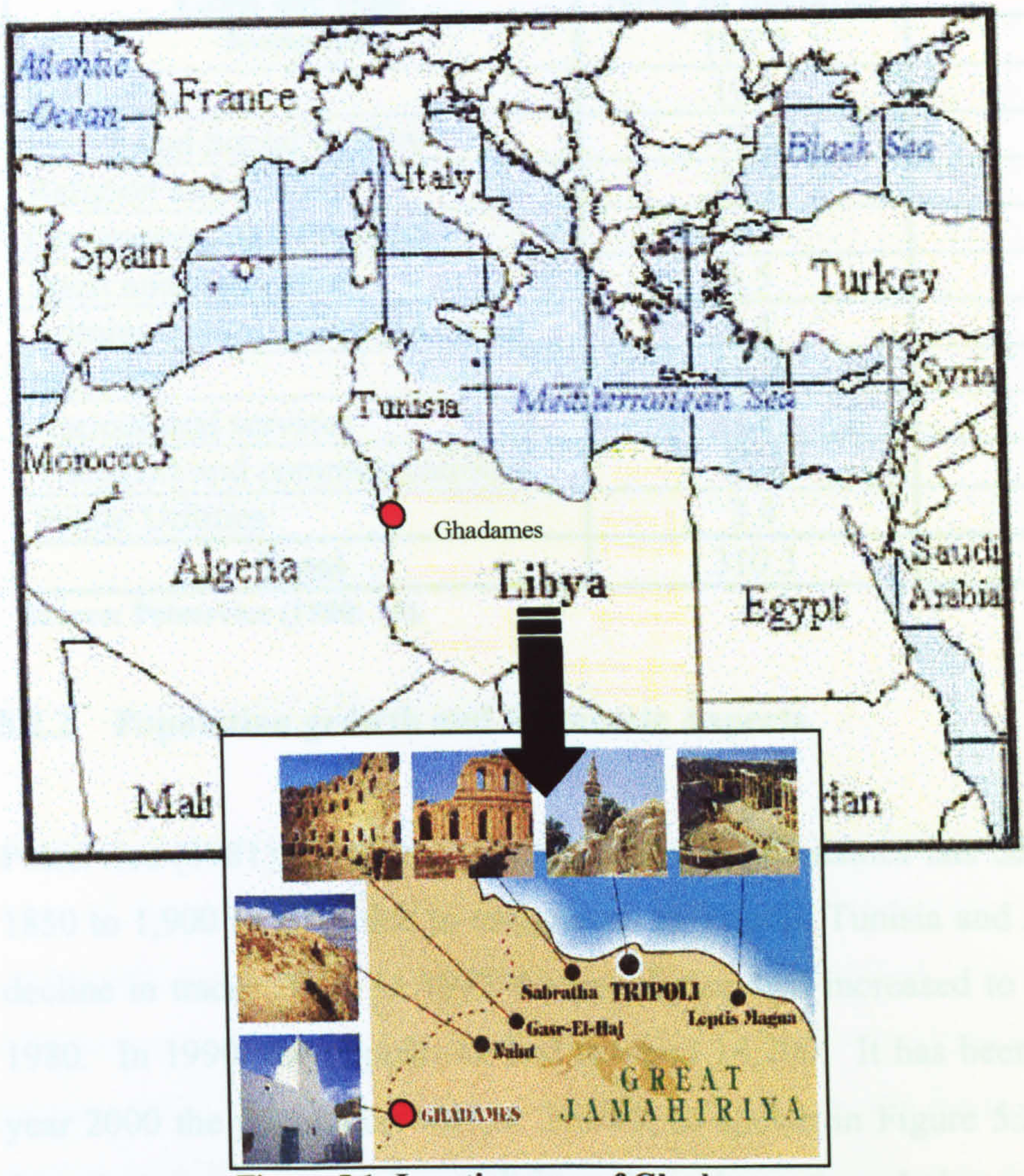


Figure 5.1: Location map of Ghadames

Ombark, (1989) mentions that Ghadames owes the existence of its water resources to the artesian spring called 'Eyn El-Faras' (i.e. horse's spring) which dates back about 4,000 years, which provided water for the irrigation of agricultural land as well as necessary domestic uses. In fact, the water was distributed intermittently to each building from that spring through small channels underneath the old town by manual control. For more details about the historical background of Ghadames, the Author recommends the following references to be reading, such as Shiaboub (1979), Eldblon (1960), Polservice (1980) and Shawesh (1996).

The public facilities are located in the city centre, as shown in Table 5.1 with their areas which include the educational, health, religious, markets, administrative, cultural sport and recreational buildings, etc.

Table 5.1: Land use of the existing layout of the master plan of Ghadames.

Land use type	Area in hectares	%
Residential	105.9	35.2
Education	19.1	5.9
Health and Social welfare	19.6	5.6
Religion and Culture	29.2	8.8
Commercial and Business	16.7	5.4
Sport and Recreation	6.5	2.4
Administration and public areas	6.4	2.1
Industry	20.3	9.4
Agricultural services	1.0	0.5
Transport and communications	82.2	23.3
Public Utilities	3.4	1.4
Total	310.3	100

Source: Polservice (1980: 16).

5.2.2 Population growth and Economic Aspects

Polservice (1981) states that the population in Ghadames has decreased from 7,000 in 1850 to 1,900 in 1952 due to emigration to Tripoli, Tunisia and Algeria because of the decline in trade. Then in 1973 the population had increased to 4,000 and to 5,400 by 1980. In 1990, the population had reached 14,700. It has been estimated that by the year 2000 the population will be 20,000, as shown in Figure 5.2. This growth results from improved economic conditions throughout the whole country since September 1969. Figure 5.3 shows Land Use map of Ghadames presenting the location of both the old and new towns.

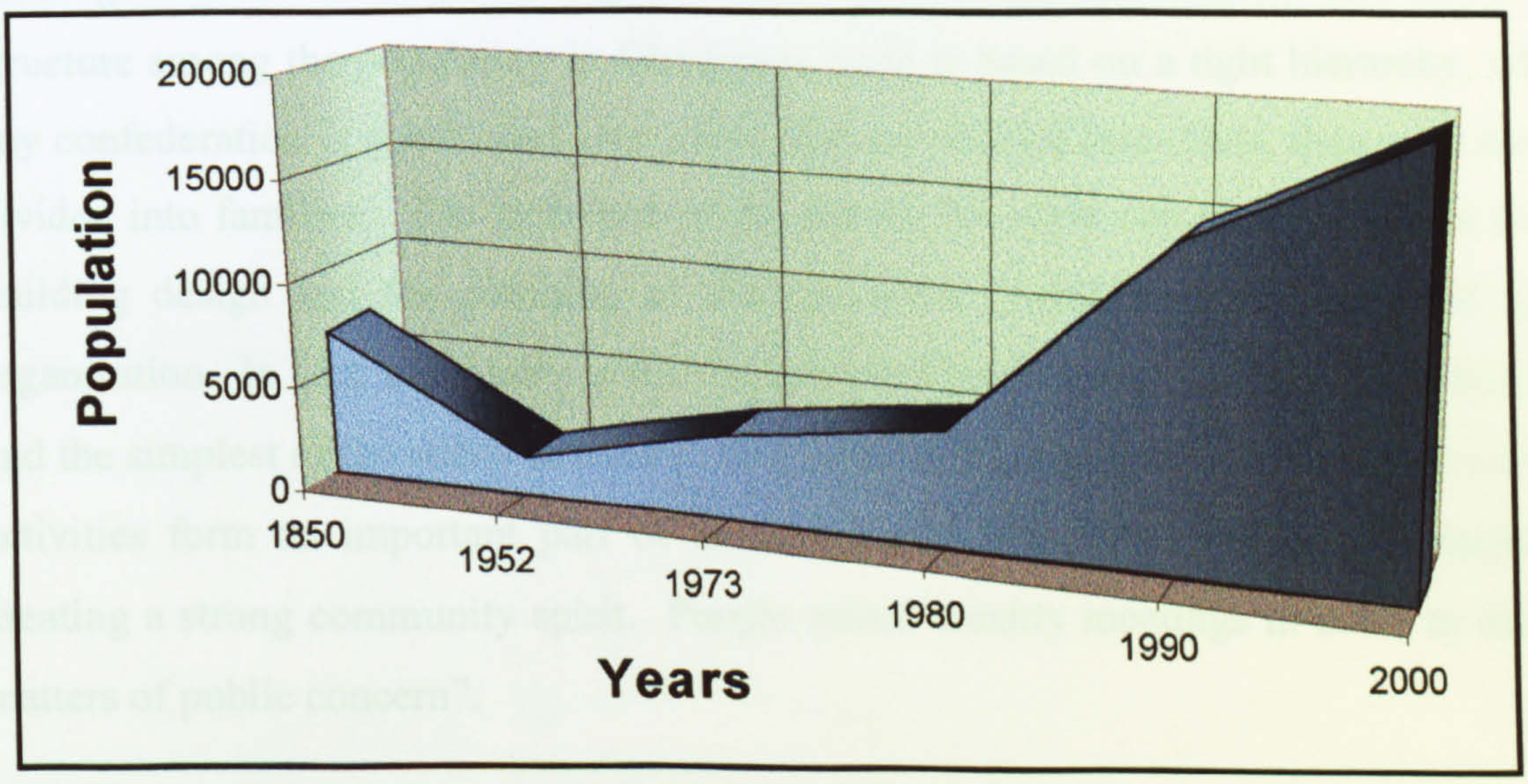


Figure 5.2: The population growth in Ghadames. Source: Polservice (1981).

The old town of Ghadames was a meeting place for caravans coming from the interior of Africa bringing gold, leather, hides and slaves. While on the return journey they carried sugar, cotton, cloth, and other products from Europe and the coast of the Mediterranean Sea. Also, Ghadames provided shelter for the caravans, which were protected by the nomadic 'Tuareg' tribe, who lived around the oasis, and were paid a levy by the Ghadamesian traders. Consequently, the majority of the population worked in trans Saharan trade. This kind of work was the essential basis for the past growth and the present development of Ghadames since the discovery of the oil in Libya (i.e. salt production and agriculture).

5.2.3 Social and Cultural way of life

Information on the social life in Ghadames before the Islamic period is very limited. Most of the written information came from foreign observers, who depended almost exclusively on legendary and literary sources. Therefore, this section relies on the information that has been collected during the interviewing time in the field-work in the summer 1997, together with the author's information and background of this area. It aims to highlight the real issues, which enable the occupants to cope with this harsh environment.

From general observations during the field work, it has been noted that the social structure among the population in Ghadames oasis is based on a tight hierarchy, where any confederation is subdivided into tribes that are divided into clans, then each clan is divided into families. The influence of the family life style can be clearly seen in the building design and the planning of the old town, particularly in respect of space organisation. In fact, the family in the old town of Ghadames is the most important unit and the simplest of the social structure. Shawesh (1992) states that " Social and cultural activities form an important part of the every day life of the people of Ghadames, creating a strong community spirit. People attend weekly meetings in order to discuss matters of public concern".

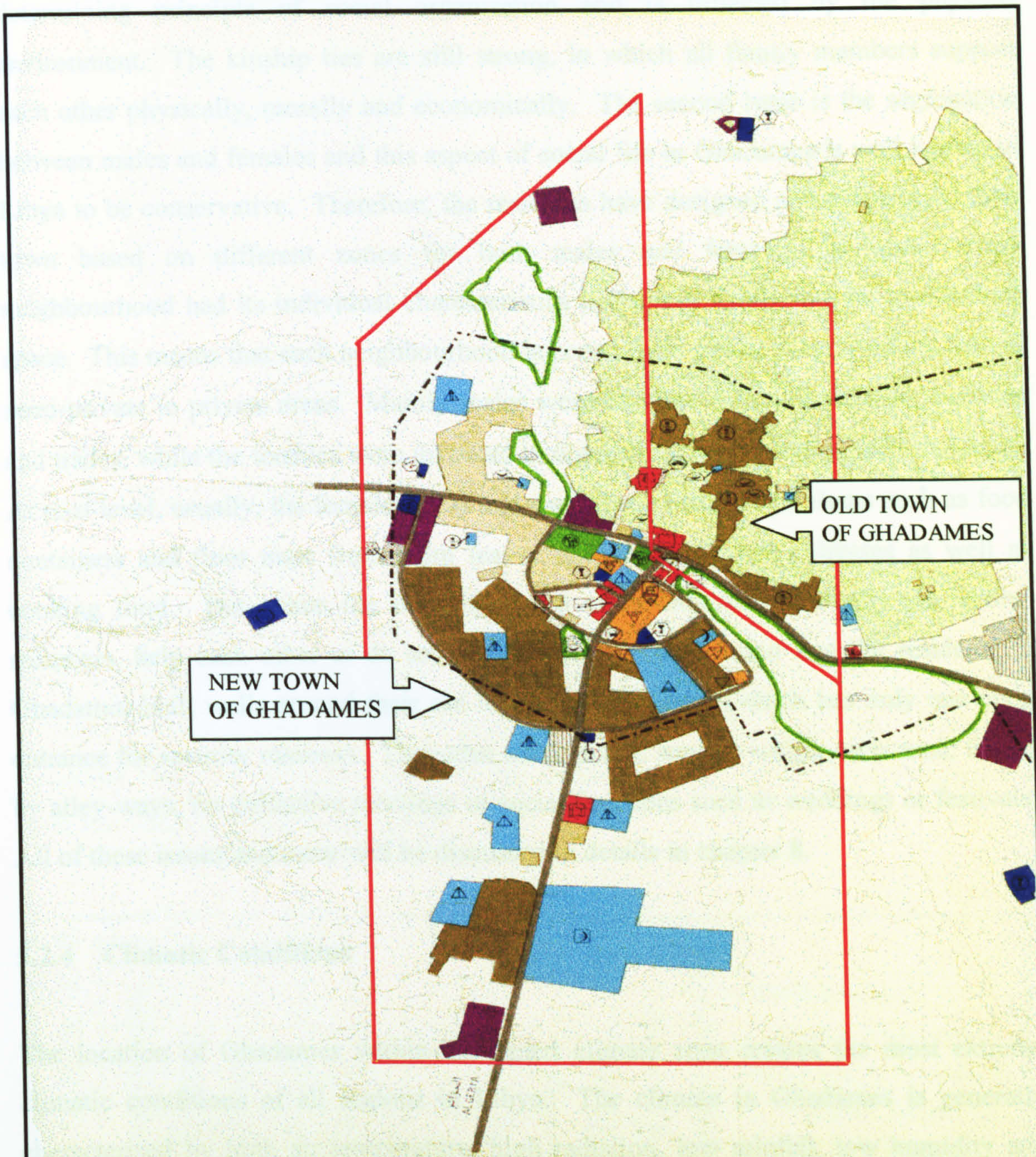


Figure 5.3: Land Use map of Ghadames showing the location of both the old and new towns.

Where:
- Government & Institution Area
- Residential Area
- Commercial Area
- Public Buildings
- Green & Recreation Areas
- Cemetery
- Industrial Areas

In Ghadames, as in most Arabic and Islamic regions, kinship structure is the determining principle of social organisation and is reflected by the physical environment. The kinship ties are still strong, in which all family members support each other physically, morally and economically. The second issue is the segregation between males and females and this aspect of social life in Ghadames is well known in Libya to be conservative. Therefore, the residents have designed and constructed their town based on different zones for both males and females, in which every neighbourhood had its individual characteristics and every family had its own private space. This means that each neighbourhood is zoned from public to semi-public then to semi-private to private areas. Mainly males were involved with commercial activities and trades, while the females were involved in domestic activities inside their buildings. At roof level, usually, the females meet and manufacture traditional items such as food containers and floor mats from palm leaves, traditional women's dresses as well as cooking food. But, when the buildings need to be maintained usually all family' members, help each other to do so. Furthermore, it was found that the residents in Ghadames built walls around their old town and each zone (which has only one main entrance for security reasons). They also made public squares within each zone, linked by alley-ways, for collective meetings or social functions such as weddings or festivals. All of these issues and more will be discussed in details in chapter 8.

5.2.4 Climatic Conditions

The location of Ghadames within the desert climate zone creates the most extreme climatic conditions of all regions in Libya. The climate in Ghadames is generally characterised by high air temperature, high radiation, low rainfall, low humidity and many sandstorms. The weather in Ghadames in the summer season is hot-dry throughout the day time and cool/windy during the night time. While in the winter season, it is very cold during the night but warm during the day time due to sand-hills and the wind-breaks of palm-trees that surrounded the oasis. Figure 5.4 demonstrates the 8 forms of general conditions in the world showing the dry desert condition and associated hot-dry climate prevalent in Libya and particularly in the Ghadames oasis.

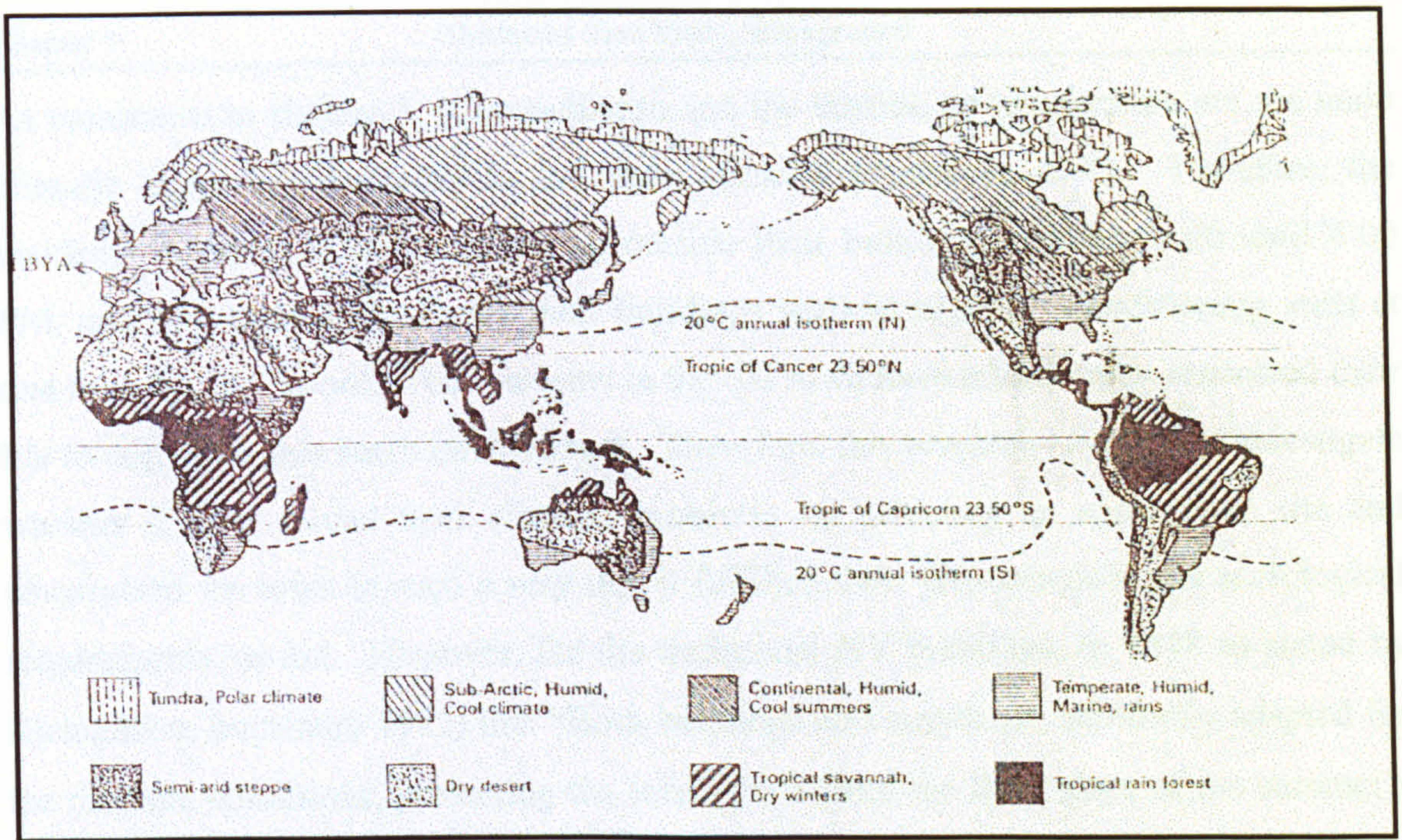


Figure 5.4: Climatic conditions of the World.

In addition, Figure 5.5 shows the severe summer condition when the weather is hot throughout the day, the air temperature sometimes rising to more than 47ºC and falling to 30ºC during the nights. In winter, the weather is cold at night, reaching 0ºC, but there is some warmth during the day, because of the surrounding sand hills. Rainfall is generally very low and non-existent in the summer months, which are associated also with low values of relative humidity.

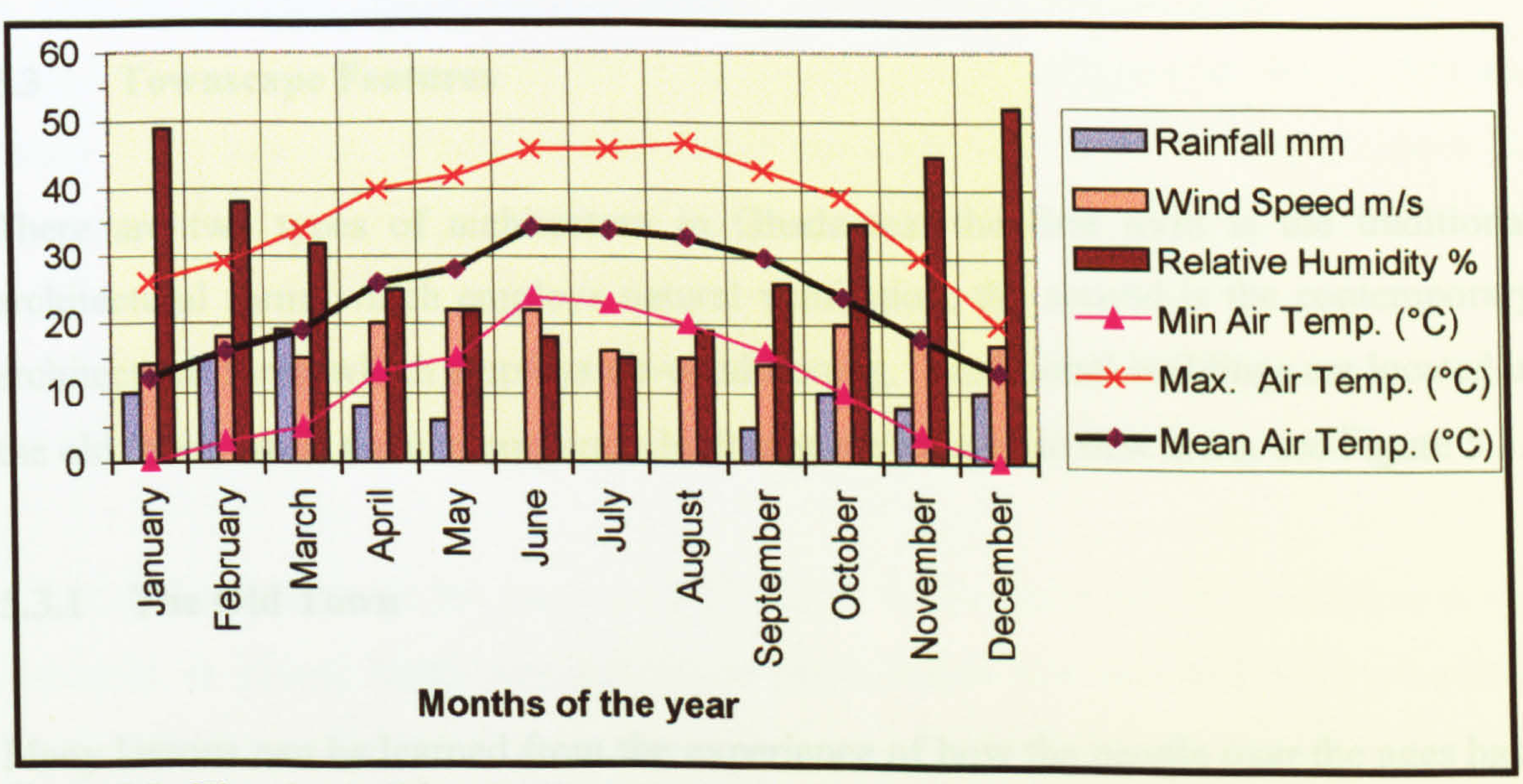


Figure 5.5: Climatic conditions in Ghadames Oasis of the year 1997.

As mentioned in chapter 3, solar radiation and the outside air temperature are the main climatic factor in Ghadames as the latter rises to more than 47°C. Therefore, the residents in the new town can not go outside their buildings between 2:00 until 6:00 PM, and they cannot stay inside their buildings without using air-conditioning units at that time (i.e. AC is on). The residents in the old town have traditionally organised their life to cope with this harsh environment. Therefore, this research is aimed to investigate whether if they solved their climatic problems by selecting an appropriate site and constructed the town in such a way that it fulfilled their physiological and sociological requirements, or not. However, for the traditional NV buildings, in 1848 as stated by Richardson, (reprinted 1972) that "Both buildings and streets are admirably adapted for the climatic conditions, protecting the inhabitants from the fiery glare of the summer's sun, and the keen blasts of the winter's cold".

Nevertheless, all of these facts will be discussed in more detail in chapter 8, especially in the new town where there are no any shaded places or alley-ways as in the old town in terms of the outdoor comfort issues. But generally, there are many lessons that could be learned from the survey described in chapter 4 applied specifically in Ghadames oasis, especially from the traditional design form point of view and as well as the planning of the old town.

5.3 Townscape Features

There are two types of architecture in Ghadames: the first form is the traditional architectural form, which employs natural ventilation; the second is the contemporary architectural form, which employs air-conditioning. Traditional buildings are located in the old town, while the contemporary buildings are located in new town, see Figure 5.3.

5.3.1 The Old Town

Many lessons can be learned from the experience of how the people over the ages have constructed dwellings to satisfy their social needs whilst providing a built environment of good quality. It represents a unique traditional human settlement, and is considered to be one of the best examples of Libyan towns. In addition to that, the old town of Ghadames consists of about 1300 dwelling units, mosques, markets and other public squares, where the people meet each other. It has a total area of 82 hectares, including buildings, gardens, public places and palm-groves.

5.3.1.1 Building Form and its character

The traditional architecture in Ghadames which consists of an elaborate composition of a variety of space ranging from extremely well sheltered rooms on the ground floor to the completely exposed roof. This architecture is unique in that it combines compactness with minimum exposure to the sun to provide privacy for the residents, as shown in figure (5.6, 5.7 and 5.8). Also, each building is surrounded by other buildings on three sides, and the façade of each building faces the alley-way, which is covered to provide shadow for the people to sit or meet and walk comfortably.

Additionally, the people in old Ghadames town have a very special way to use each space inside the building according to the climatic changes in each season. For instance, the family uses the heavyweight construction of the ground floor for the summer season and the relatively lightweight first floor for winter. Also, the open roof is used for sleeping during summer nights. Therefore, in the old town of Ghadames some buildings are still occupied and in reasonably good condition even though they are nearly 600 years old. When residents were moved to the nearby new town about 20 years ago, some parts of the traditional buildings in the old town unfortunately started to deteriorate.

5.3.1.2 Building Method and Materials

A noticeable feature of the traditional buildings in the old town of Ghadames is the similarity in shape, form, size and space organisation and distribution of elements. Most of these types of buildings are three storeys high with a courtyard in the middle.

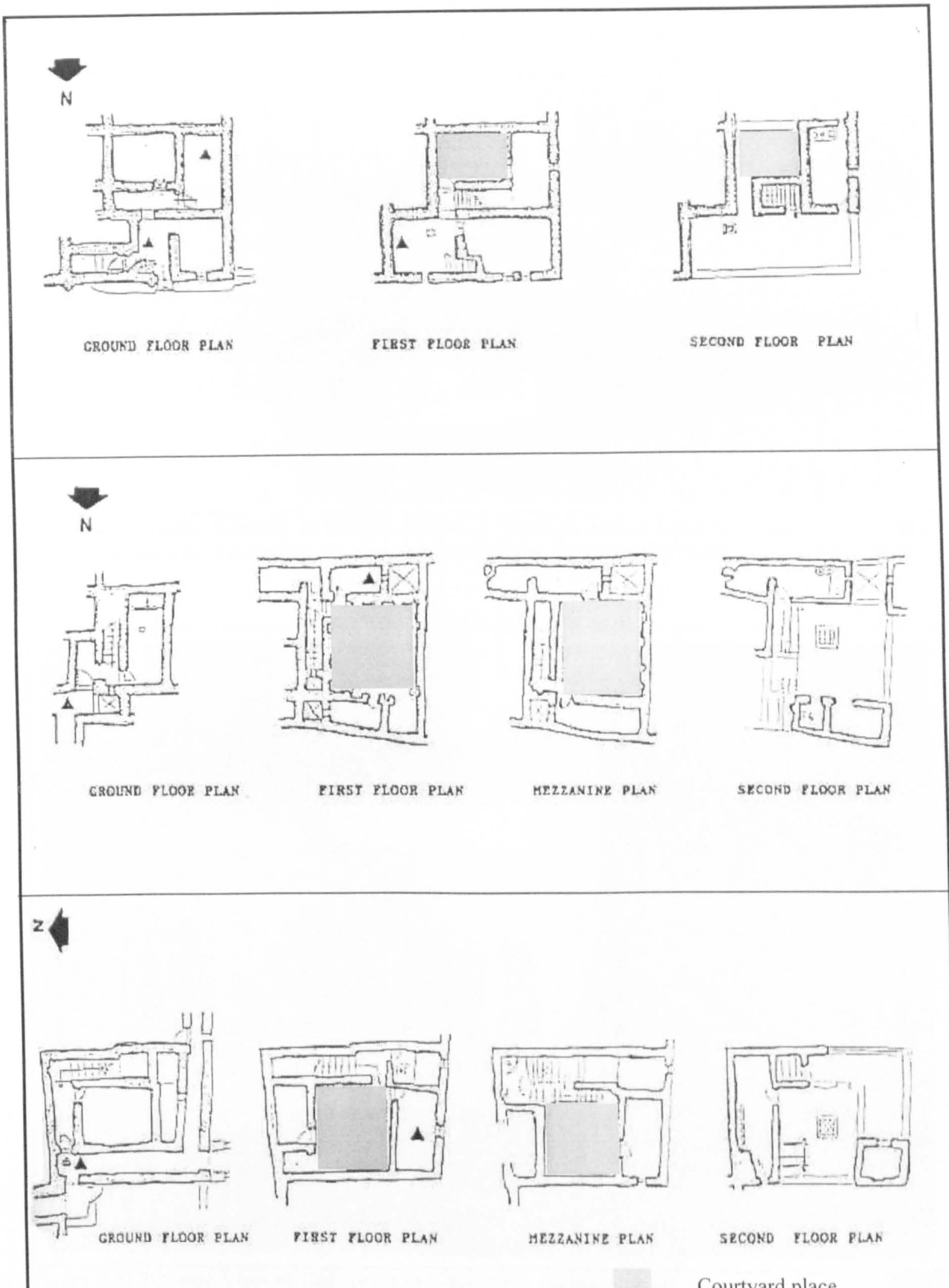


Figure 5.6: Some Examples of Traditional Building's in the Old Town of Ghadames, 1997.

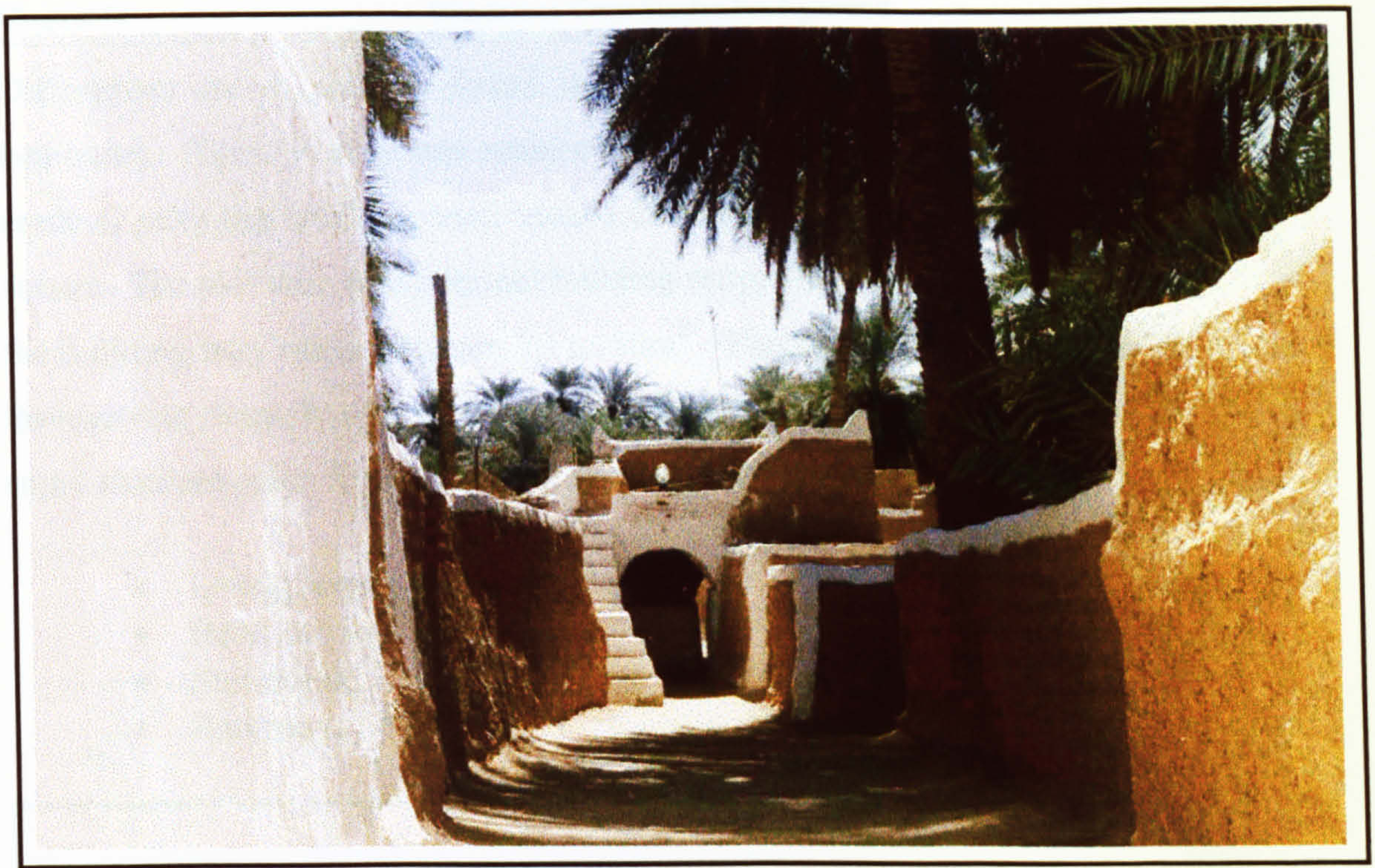


Figure 5.7: Typical Example of shaded Alleyways Open to Public Square, presents white plaster colour of walls, where buildings are surrounded by Palm Trees, at Old Town of Ghadames, 1997.

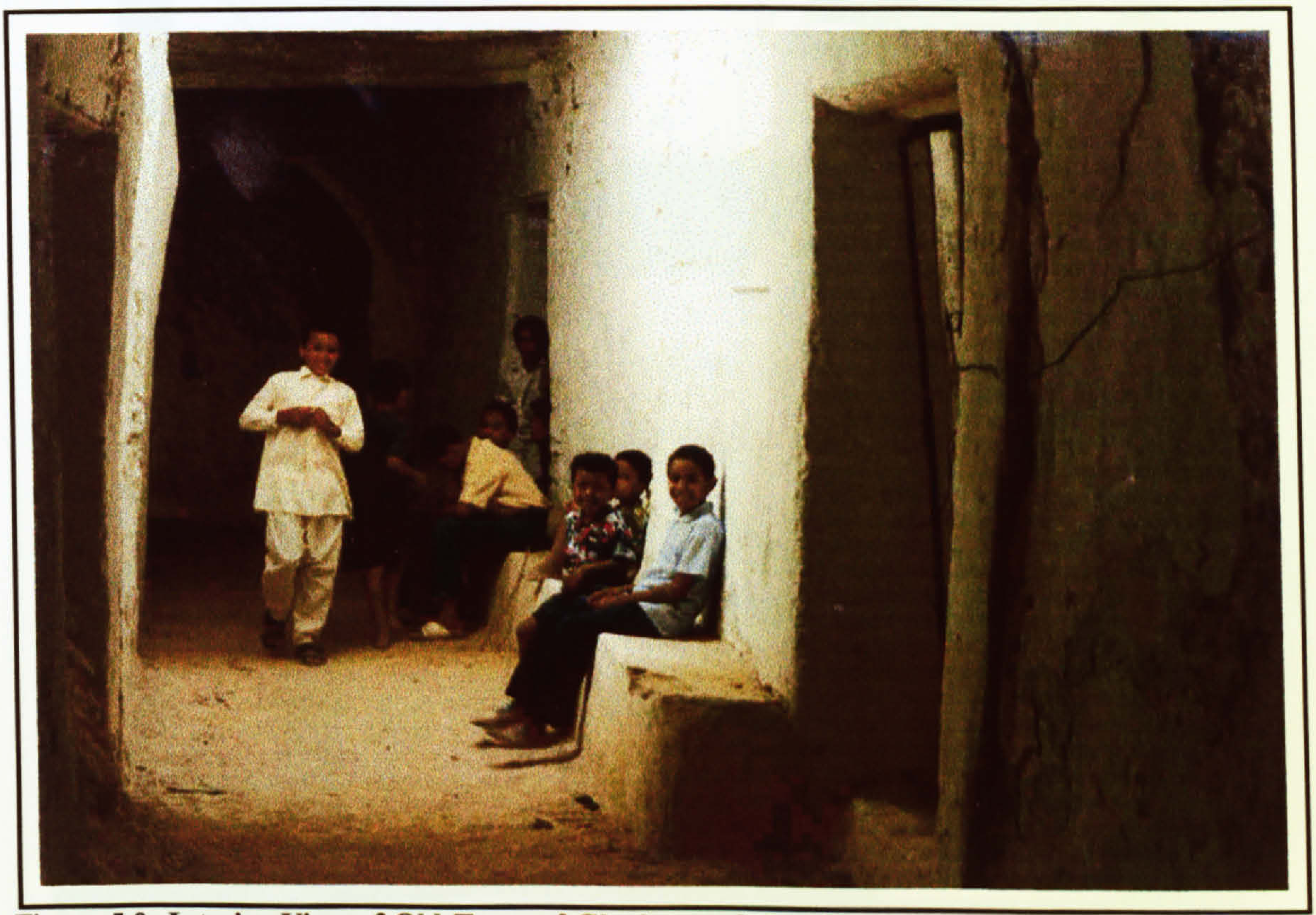
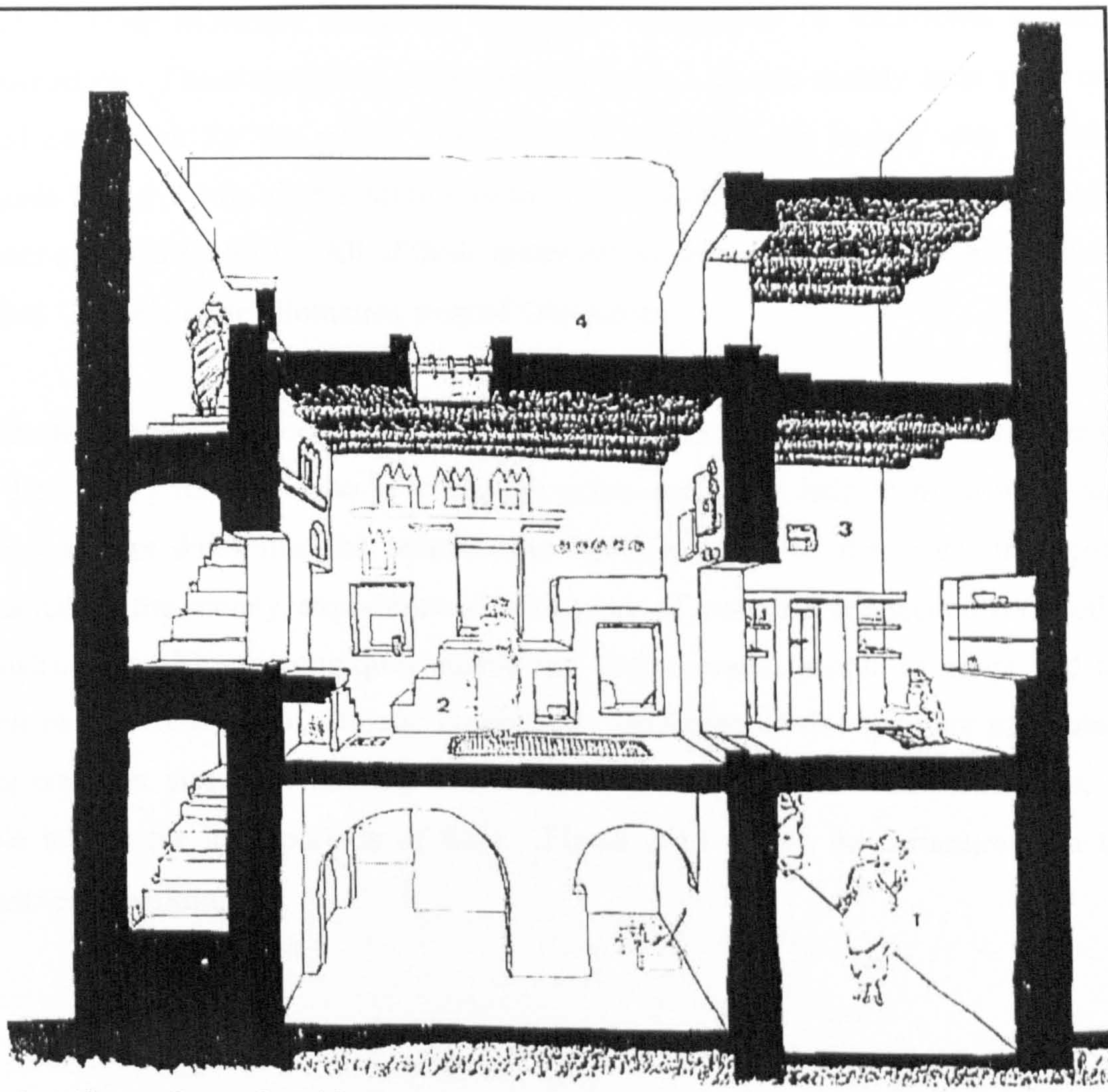


Figure 5.8: Interior View of Old Town of Ghadames shown Shaded Alleyways in which Children can play safely and thermally comfortable during the day time despite the severe outdoor climate, and also shows entrances of Compactness Traditional Buildings, 1997.

Differences are sometimes found in the area of the courtyard, or the number of bedrooms. There is only one main entrance door to each traditional building, which, made of palm tree trunk, opened usually directly to the alleyway or a small semi-private square. The plot area of traditional building range from 25 to 50m^2, and the total area of the building may range between 70 to 80m^2. Figure 5.9 shows a sectional perspective through one example of a traditional building in the old town of Ghadames. There are some standard areas for the inside elements of the traditional buildings:

- Living room (courtyard); 10 to 16 m^2;
- Bedroom area; 5 to 12 m^2;
- Storeroom; 20 m^2; and
- Bathroom ; 4 to 6 m^2.



1- Alleyways Street at Ground floor
2- Courtyard as an internal room at first floor.
3- Bedroom at first floor.
4- Roof and Kitchen (Women's area level)

Figure 5.9: Sectional Perspective a through Traditional Building in the Old Town of Ghadames.

The first floor, has a larger area because of its projection over the street level, including a storeroom for agricultural tools and toilet, as has been shown before in Figure 5.9. A flight of stairs leads to the upper floors, where a courtyard is located in the first floor with a double floor to ceiling height, which has at its ceiling a small sky window. This small opening at the ceiling of the courtyard, called an aperture, is to provide natural light and ventilation, when required, into the courtyard. The upper floor level is reserved mainly for women, where the kitchen is located, so that they are able to confine their activities, such as cooking, washing, etc.

The main influence of socio-cultural aspects on the traditional architectural design can be clearly seen in the old buildings. All of these buildings have been constructed from local building materials using the residents' experience of traditional methods of construction. These materials, as shown in Figure 5.10, are mainly lime stone or sun-dried clay brick for the walls. The building materials are mainly clay mixed with organic matter, while all the interior surfaces are gypsum plastered, and palm trunks and leaves are used for roofs. All of these materials are produced locally in the small village called *'Tonin'*, three kilometres west of Ghadames.

With the above-mentioned building materials, traditional buildings are constructed most of the time by relatives who have enough experience, with help from all when needed. Many factors determine the selection of specific types of materials; the economic structure of the society, experience of what types of materials are needed and method of construction. These techniques enable the Ghadamesian people to adapt and to live with the severe external climatic conditions. Buildings of this type are integrated into one complex structure, making it difficult to distinguish individual buildings, whilst able to last for long periods of time. Figure 5.10 shows the structure of a typical traditional building.

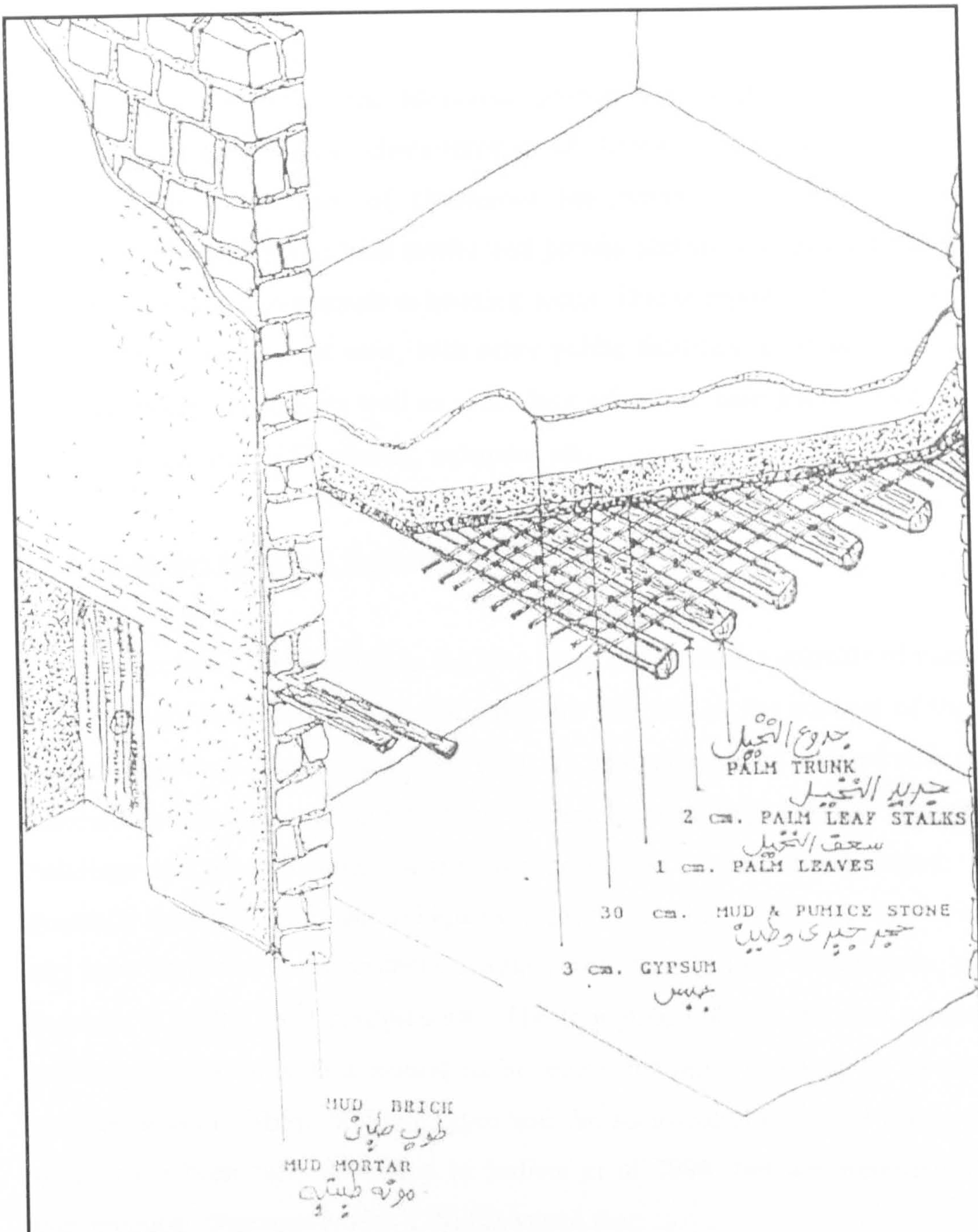


Figure 5.10: Traditional Constructed Building Materials at the Old Town of Ghadames.

The total materials requirement of a complete traditional building, as Shawesh (1996) has mentioned, are 20,000 mud bricks, 800m of palm trunk, 1,500 palm branches, 20,000 kg gypsum and 2,000 kg lime. Each building is containing about 10 doors and 3-5 windows. Actually, the whole process of construction such kind of building, usually it take one year to complete, which could be considered to be as self-help procedure.

5.3.2 The New Town

As mentioned previously, the economic growth that resulted from oil production affected the socio-physical characteristics of Libya in general and Ghadames in particular. The new town of Ghadames has witnessed a massive increased of contemporary buildings in both public and private sectors, due to the large amount of subsidies from the Government in housing sector. Due to report of Polservice (1981:69) about 3750 dwelling exist now, with other public facilities, such as hospital, primary and preparatory schools, as well as secondary school, a main public building contains local municipalities of Ghadames, mosques, etc.

5.3.2.1 Building Form and its character

The contemporary architecture in the new town of Ghadames consists of mainly single and two story buildings. These buildings are affected by the concept of the land use plan, see Figure 5.3, and Table 5.1. They are characterised by isolated structures, high standards of construction and building materials, with large outdoor spaces between buildings and modern infrastructure, and developed in randomly grouped. They are generally detached, as shown in Figures (5.11, 5.12 and 5.13). The designers of the new city have borrowed some aesthetic features from the old town architecture, which they consider to be the most conspicuous. The triangular holes in the roof parapet of each building seek to provide a natural night breeze for those sleeping on the roofs in the summer season. These building types and the socio-cultural way of life in Ghadames oasis, have been fully described in Ealiwa et al 1998, but are summarised here for convenience. Shawesh (1996: 170) has stated that:

> "From the new land use plan or the master plan of the Ghadames oasis, there was a greater amount of attention given by the Government to the public spaces, such as roads, public and commercial activities, than to the residential areas. Despite the fact that the dispersed layout provided more space, better access and facilities than the compact traditional layout of the old town, it is clear that it did not respond effectively to the social and climatic conditions of Ghasdames. The new plan for housing did not take into consideration the importance of kinship and family structure, which had been the basis for the traditional way of life and so created problems and friction between neighbours which led to social disharmony".

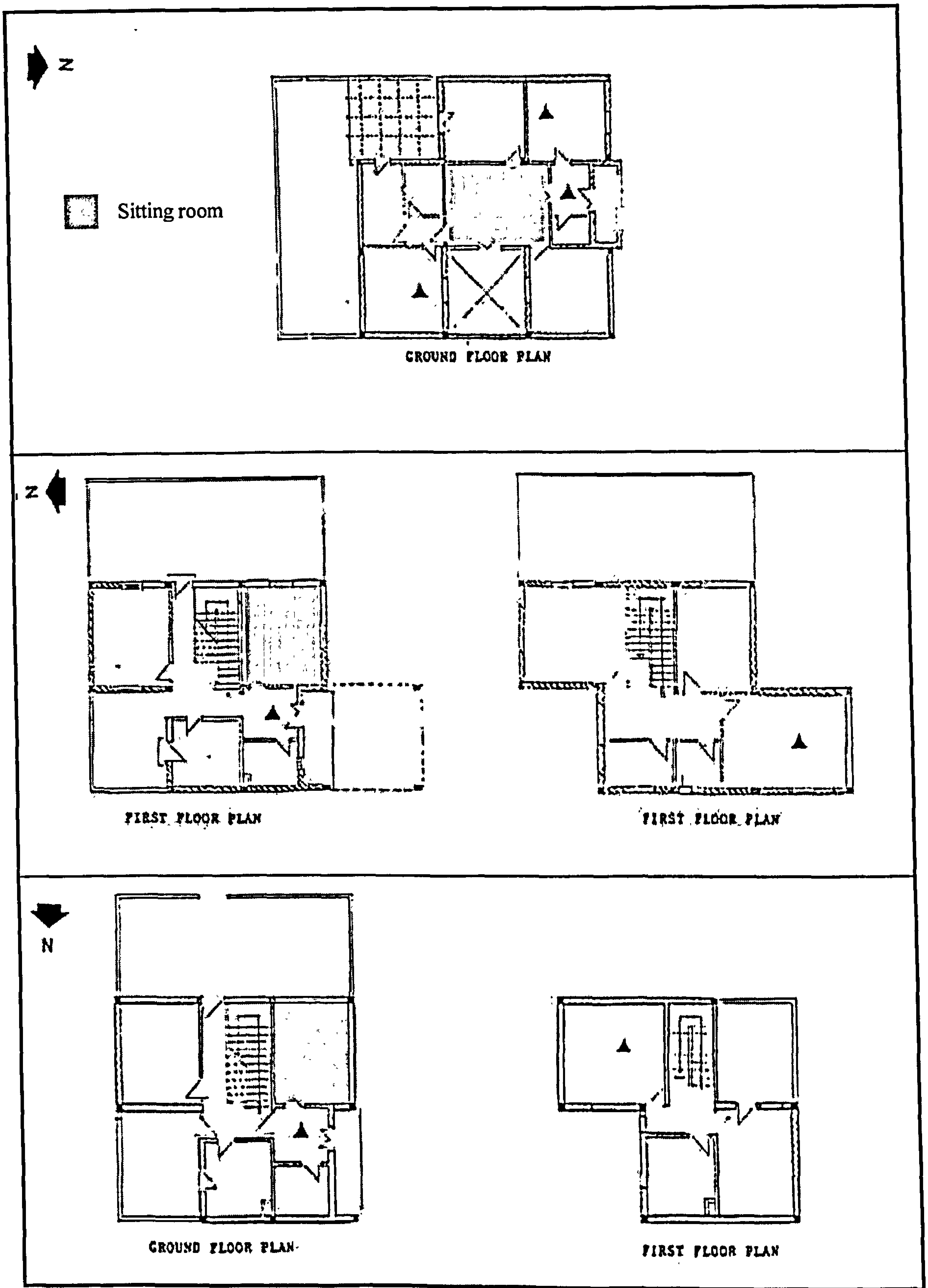


Figure 5.11: Some Examples of Contemporary Building's in the New Town of Ghadames, 1997.

Figure 5.12: Site View from New Town of Ghadames Shown Different forms of Contemporary Buildings, some of them are occupied and others are under construction, 1997.

Figure 5.13: Site View from New Town of Ghadfames Shown Some of Contemporary Buildings which are under Construction by Private Sector, using New Construction Materials, 1997.

5.3.2.2 Building Method and Materials

The modern building form ignored the values and meaning of the users moral, social and personal needs, based on Western-style design and construction methods, which removed Ghadamesian residents from their traditional way of life. Shawesh (1996) states also that "Unfortunately the design concept had a particularly large and negative impact on the user's socio-cultural factors because free standing buildings with wider open spaces around the buildings was unsuited to the environment". In addition, there is a sitting room instead of courtyard, and the kitchen always is located in the ground floor. Figure 5.14 shows the perspective section in one example of contemporary building in new town of Ghadames, 1997. In fact, there are many different types of building forms in the new town of Ghadames, which could be categorised as villas, detached, and apartment buildings. The plot area of each building is between 115 to 225m^2, with total areas of 130 to 250m^2. For the inside elements, living room area is from 15 to 20 m^2, bedroom area is between 15 to 21 m^2, kitchen area is about 12 m^2, and bathroom is between 2 to 6 m^2.

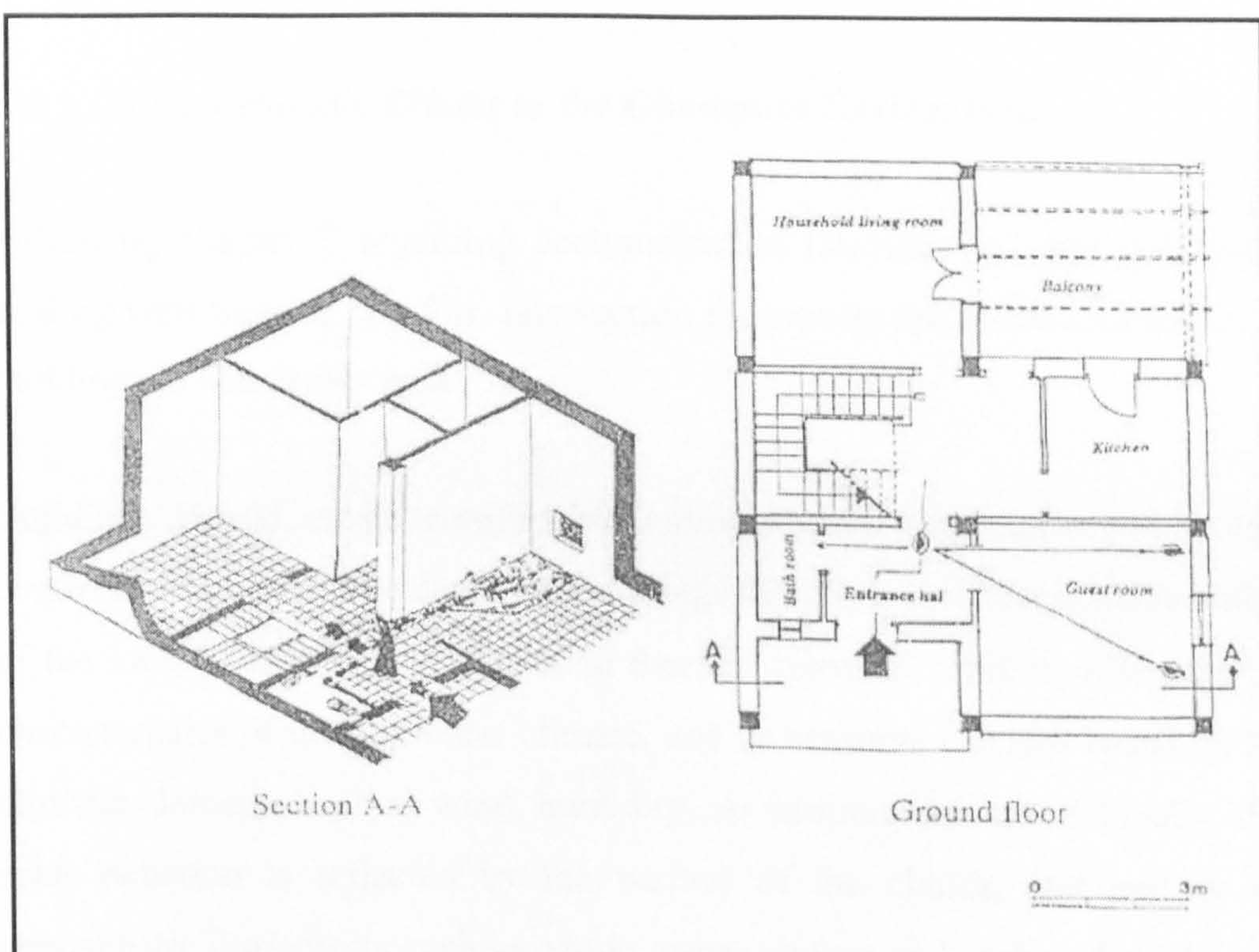


Figure 5.14: Visual Perspective Section in one example of Contemporary Building in new Town of Ghadames, 1997.

At the new town of Ghadames every thing was new for the people; new construction of building materials, new forms, and new un-shaded roads that are asphalt paved roads and passages, etc. The contemporary buildings are also characterised by a lack of similarity in terms of form or shape, size and distribution of elements. Furthermore, their openings are facing directly to the outside un-covered public spaces, and are un-protected from overlooking by other neighbours (i.e. not providing enough privacy to occupants). These issues have impacted negatively on their daily life.

The main new construction building materials are; steel, aggregate, cement, wood, mosaic, marble, and hollow cement blocks. The structure of these forms of buildings can be simply described as a skeleton framework, where reinforced concrete is used for columns, beams, roofs and floors, while hollow cement blocks are used for construction of the interior and exterior walls. All foundations, lintels and stairs are also constructed of reinforced concrete. The production of these types of materials has been increased by public schemes. Although their prices have increased, the production level is still fails to satisfy demand. This fact has badly and negatively affected on the cost of the building.

5.4 Micro-climatic Effects in the Ghadames Environment

Following chapter 2 regarding acclimatisation (sections 2.2 and 2.4) and chapter 3 dealing with thermal comfort, this section focuses on the micro-climatic in and around buildings in Ghadames area.

Buildings should create comfortable environmental conditions within enclosed and controllable spaces. The design of buildings therefore needs an understanding the effect of the local micro-climate on human thermal comfort. This involves the study of the characteristics of the particular climate, and its seasonal changes based on the principal climatic elements such as wind, humidity, air temperature, etc. Globally, the incoming solar radiation is reflected by the surface of the clouds, and part is absorbed by atmospheric ingredients such as ozone, water vapour and carbon dioxide, while a small amount is scattered in all directions by the air molecules themselves. Olgyay (1963) has described these methods of the heat transfer, as shows in Figure 5.15. At the same time, human bodies are controlled to maintain a core temperature close to 37°C, which are occur in several ways. Thomas (1996: 7-9) states that "Sensible heat loss from the skin or outer clothing surface occurs by convection and radiation, and there is a sensible heat loss during respiration". Thus, in normal conditions, the of heat loss from the body will depend on the air temperature, air velocity, clothing worn level, and the mean radiant temperature of the surrounding. However, in hot climatic regions, the atmospheric water vapour pressure has a significant effect on heat flow from the body, which needs to lose heat by evaporation. Thus Thomas also has stated that " the naked body, if shaded from the sun, can be quite comfortable at around 28-30°C and at moderate relative humidities".

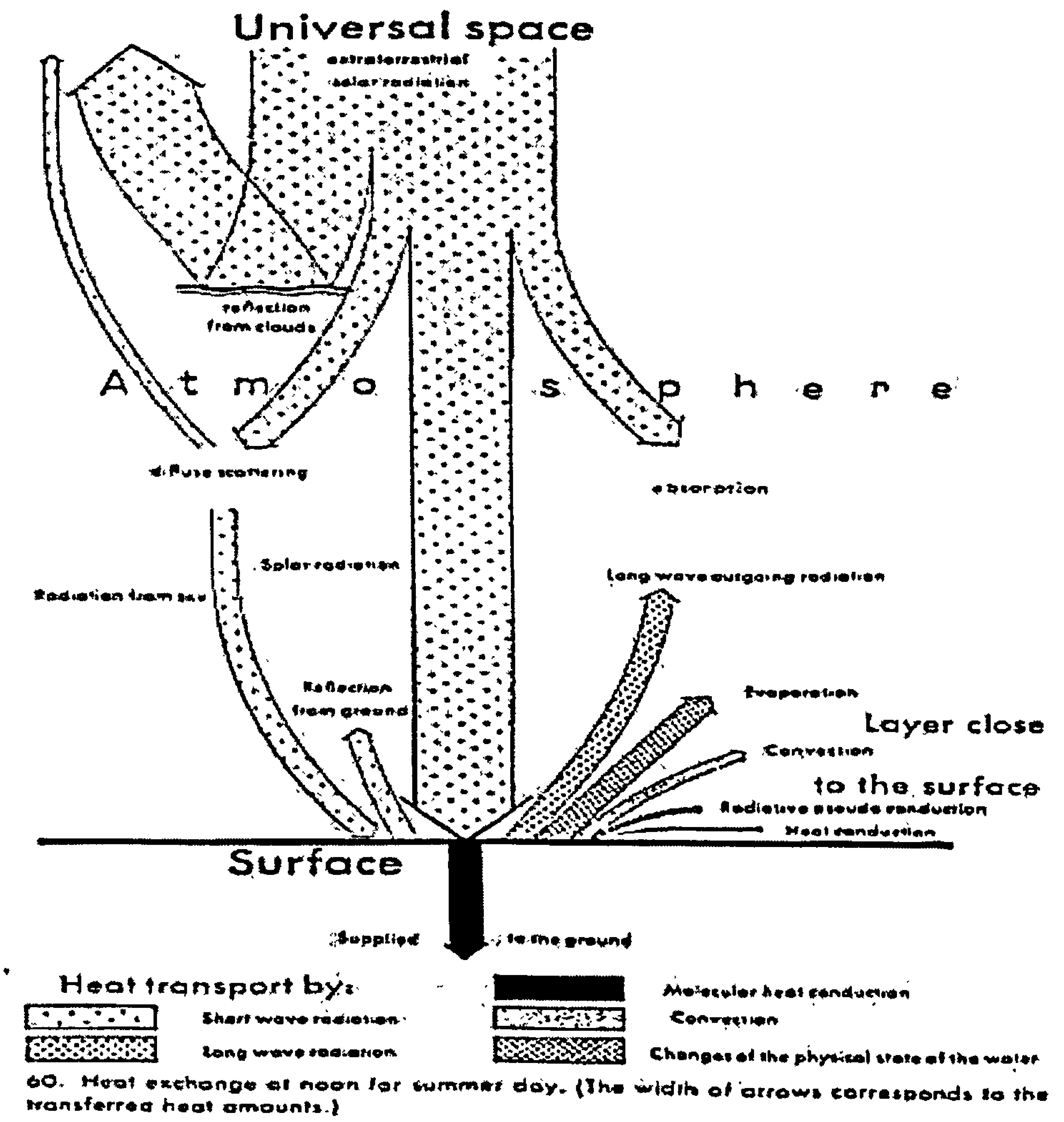
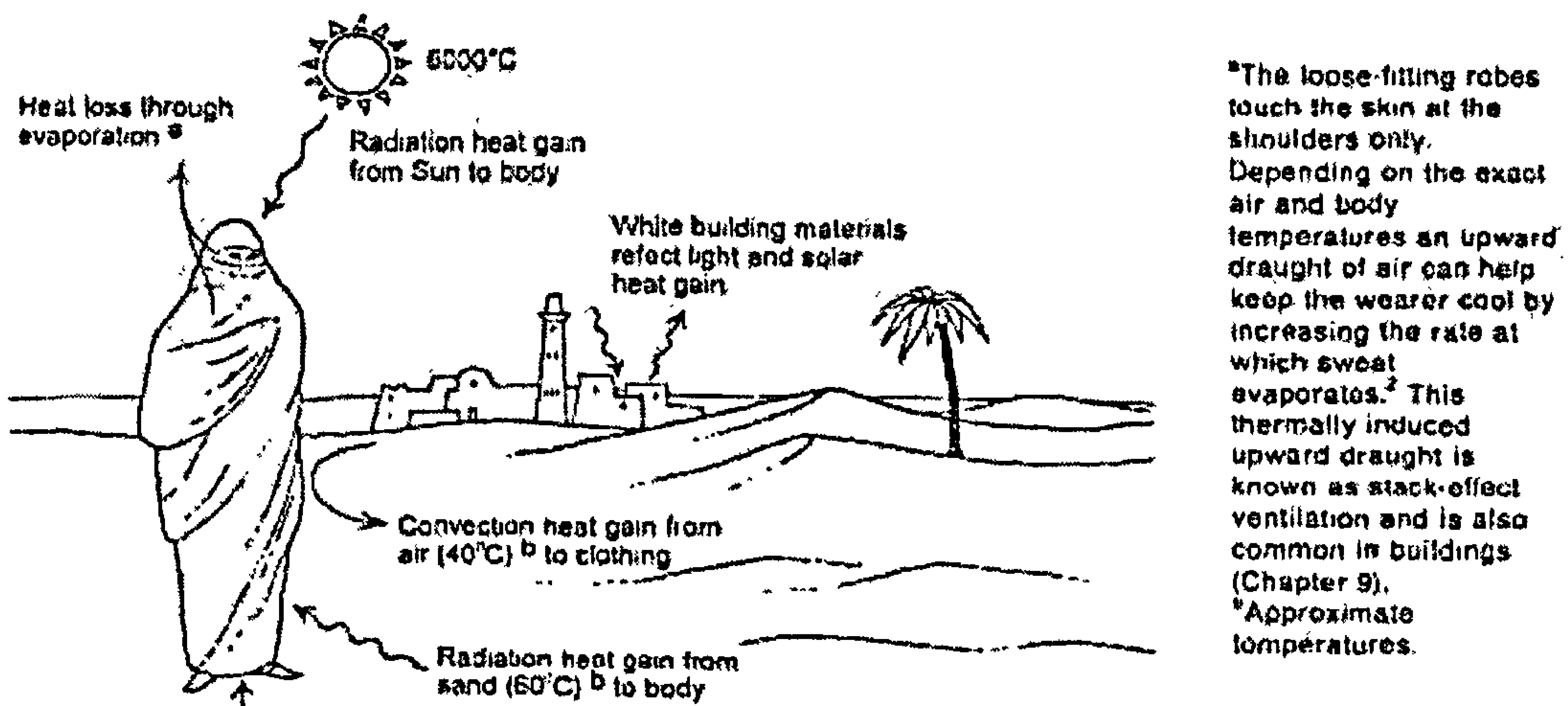


Figure 5.15: Methods of Heat Transfer. Source: Olgyay (1963).

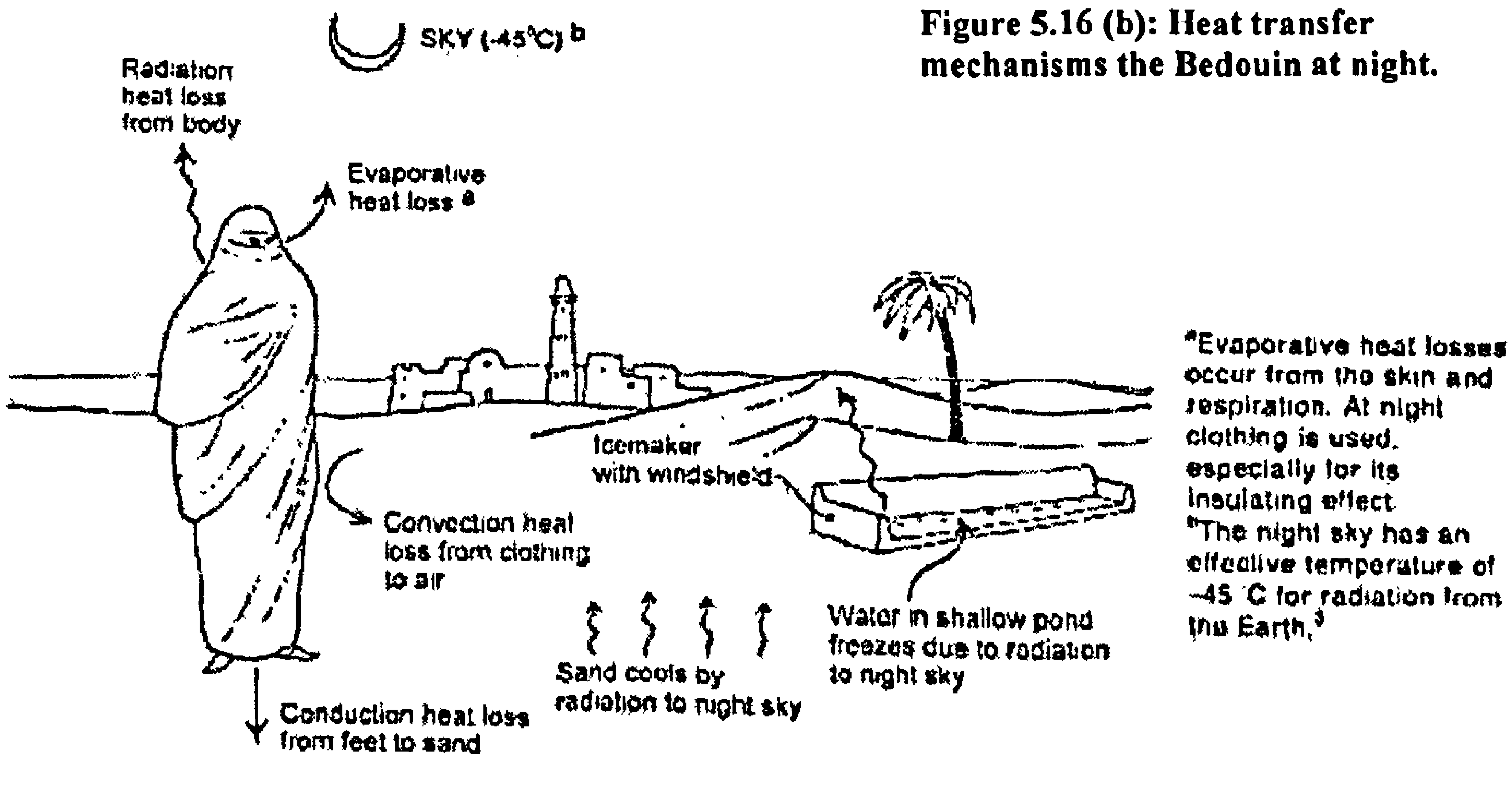
These processes are illustrated in Figure 5.16a and 5.16b, which show that as the ambient temperature rises the body's response is (a) to direct more blood to the surface, which increases the skin temperature and heat loss, and (b) to sweat to lose heat through evaporation; any human being will feel uncomfortable when these responses become significant. When the ambient temperature drops, the body will limit heat loss by reducing blood flow to the surface, which reduces the skin's temperature, and by not sweating. These mechanisms will be more effective on the body of the human being who has compensated for cold or hot climate through the use of clothing; the amount of required clothing increases as the inside and outside air temperature decreases.



△ Up
Figure 5.16 (a): Heat transfer mechanisms; the Bedouin by day.

Source: Thomas (1996)

▽ Dawn
Figure 5.16 (b): Heat transfer mechanisms the Bedouin at night.



The perception of comfort involves a large umber of variables, some of which are physical and others personal (see chapter 3). There are many outdoor environmental factors that directly or indirectly influence comfort level, such as wind, noise, ventilation, shadow, kind of the soil, water bodies, and trees and vegetation, etc. However, there are several global and local factors that determine the wind direction and velocity over any region, such as the seasonal differences in atmospheric pressure, the rotation of the earth, as well as the topography of the given land and its surroundings. Architects, who design or construct a building, should consider these factors in order to achieve indoor thermal comfort.

The Ghadames region, has its own climatic conditions, which as mentioned in chapter 2, differ from other regions in Libya (e.g. coast regions). Climatic conditions on a specific area can vary substantially from the available macro-climate weather data, depending upon its altitude, vegetation, and natural features of terrain. These factors will, in many cases, modify the temperature, humidity, the direction and velocity of wind and precipitation of rain on exterior surfaces of a building, and amount of radiation. Landscaping also has an implication to control the wind to provide a batter environment. For instance, Figure 5.17a shows different degrees of effects of ground cover on the proportion of radiation absorbed. The designer in hot dry climate must be concerned with controlling the micro-climate within the space enclosed by the structural shell, to provide an acceptable environment, without resorting or increase to use mechanical or electrical devices. Also, Figure 5.17b shows the impact of the landscaping on the air movement. Vegetation is an important geographical element that affects the micro-climate. It could be seen clearly in Ghadames case study, where the people of the old town had constructed their buildings surrounded by palm trees, as shows in Figure 5.18, while, this issue has been neglected totally in the new town. Vegetation can lessen the impact of solar radiation on a building in three ways, as shows in Figure 5.19, by:

a) reflecting a portion of the solar radiation striking its surface;
b) shading building surfaces from the direct radiation of the sun; and
c) absorbing varying amount of direct or reflected radiation, without adversely affecting the benefits of good air movement.

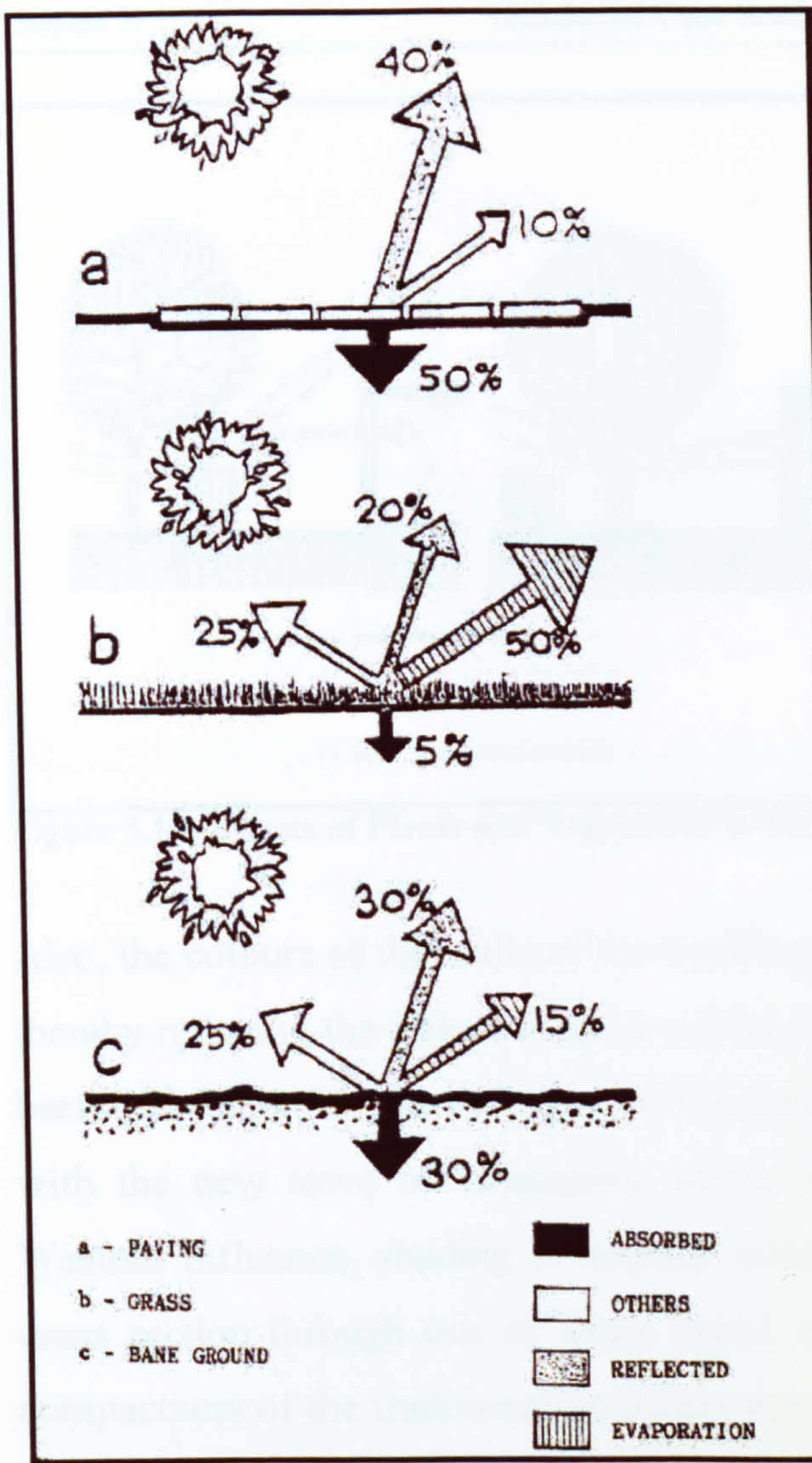


Figure 5.17a: The effect of ground surfaces on the Proportion of Radiation Absorbed. Source: Konya (1980).

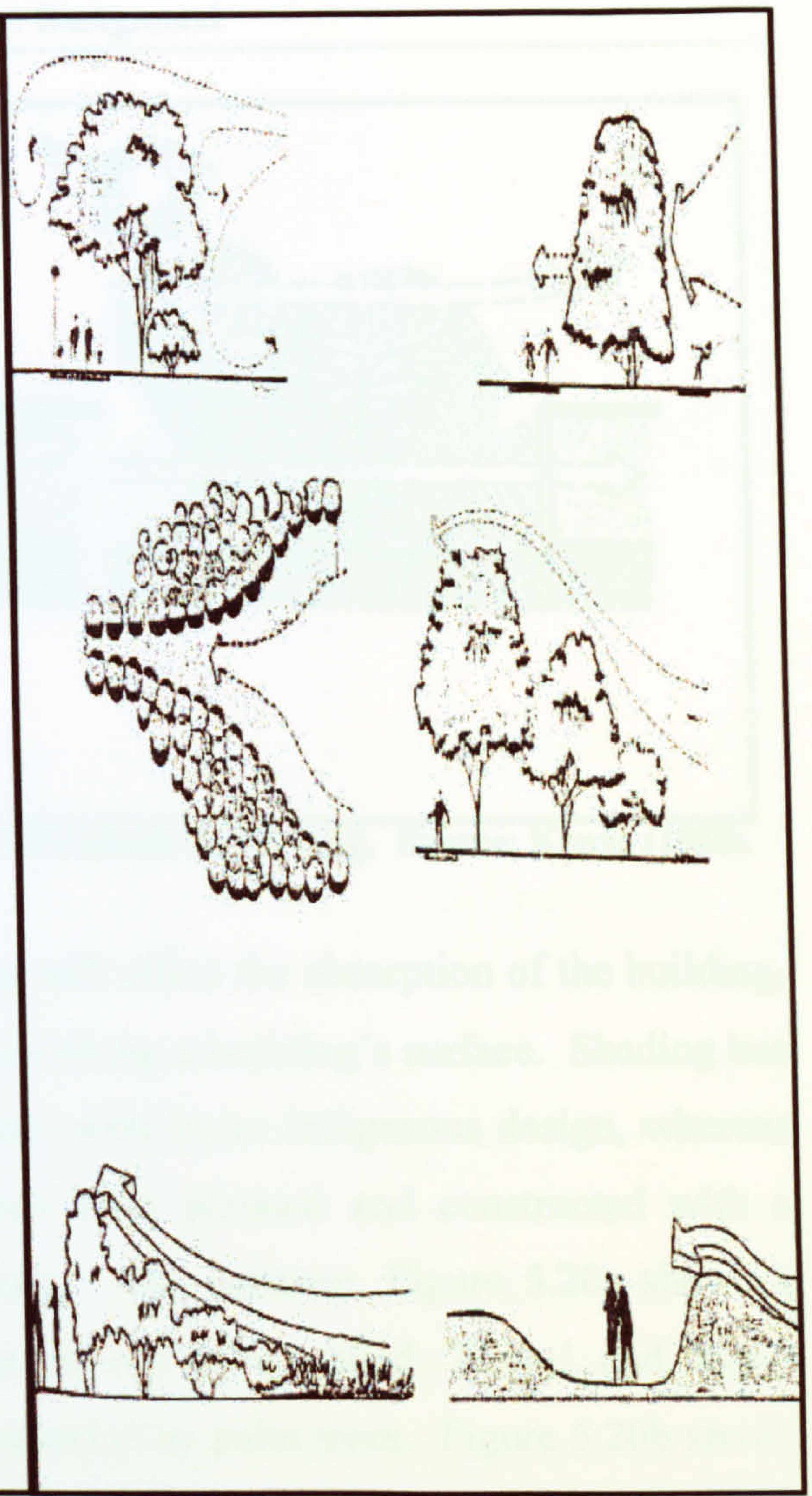


Figure 5.17b: Impact of the Landscaping on the Air Movement. Source: Robinette (1972).

Figure 5.18:

Water stream channels and palm trees together with walls surrounding the old town of Ghadames, and play the main as primarily natural features to impact on solar radiation

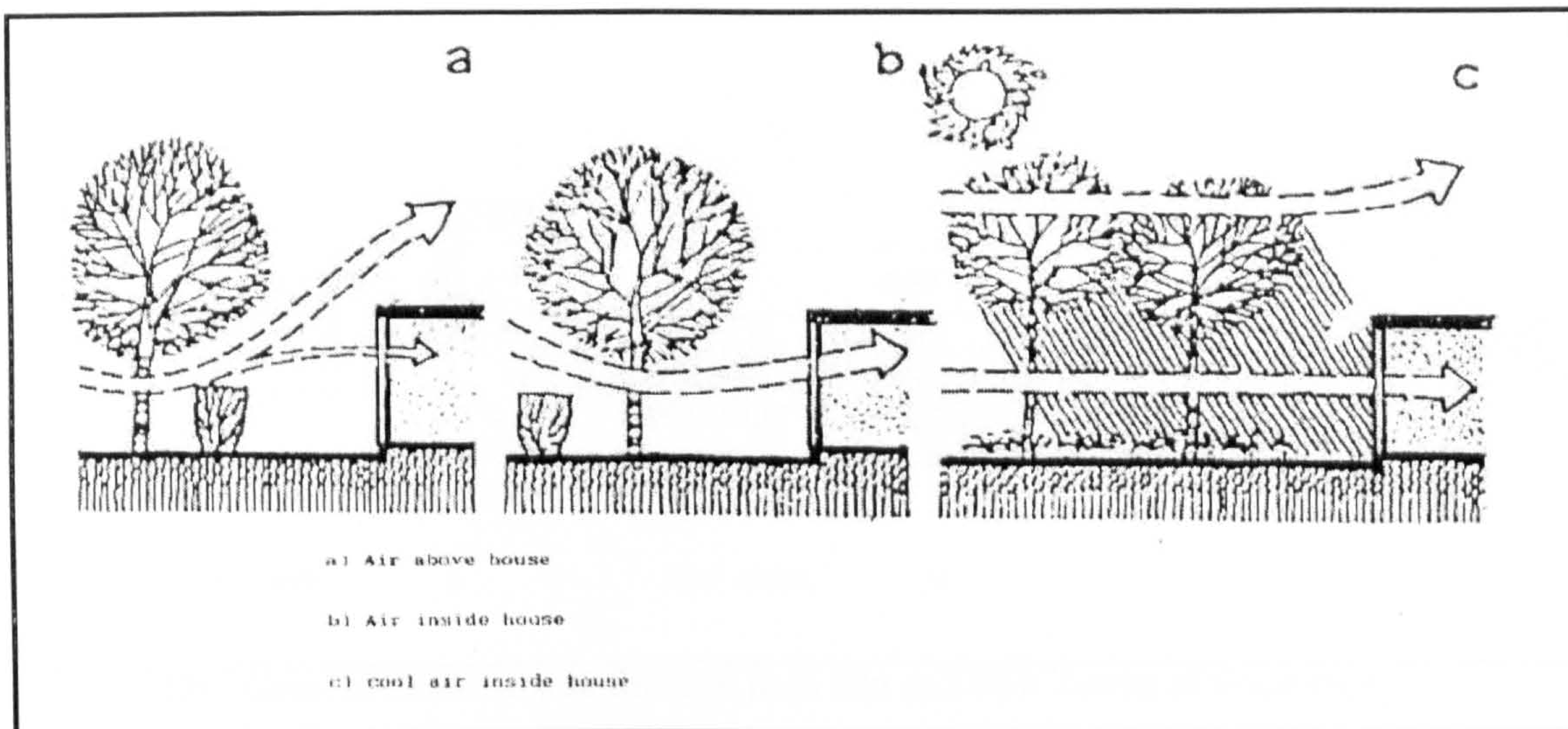


Figure 5.19: Effects of Plants and Vegetation in air movement on building. Source: Konya (1980).

Also, the colours of the walls of the buildings will affect the absorption of the building, thereby reducing the effects of solar radiation striking a building's surface. Shading has been considered, in the old town of Ghadames with its an indigenous design, whereas with the new town of Ghadames which has been planned and constructed with a Western influence, shading is notably lacking. For instance, Figure 5.20a shows a cross section through one of Main Street in the old town, called *'Tusku'*, and shows compactness of the traditional buildings surrounded by palm trees. Figure 5.20b shows a general cross section through both old and new towns.

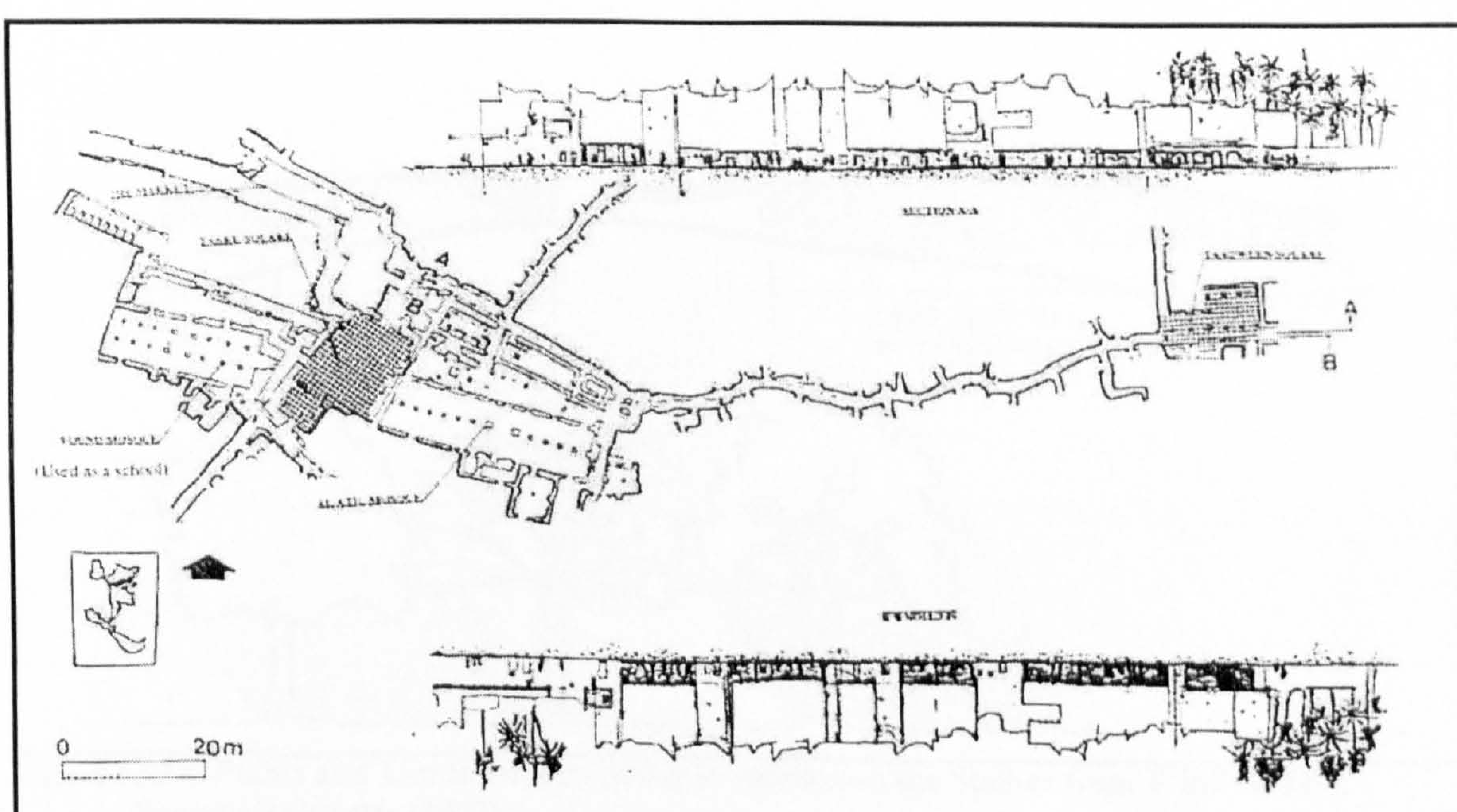


Figure 5.20a: Plan of 'Tusku' Neighbourhood and its Cross section through Old Town of Ghadames.

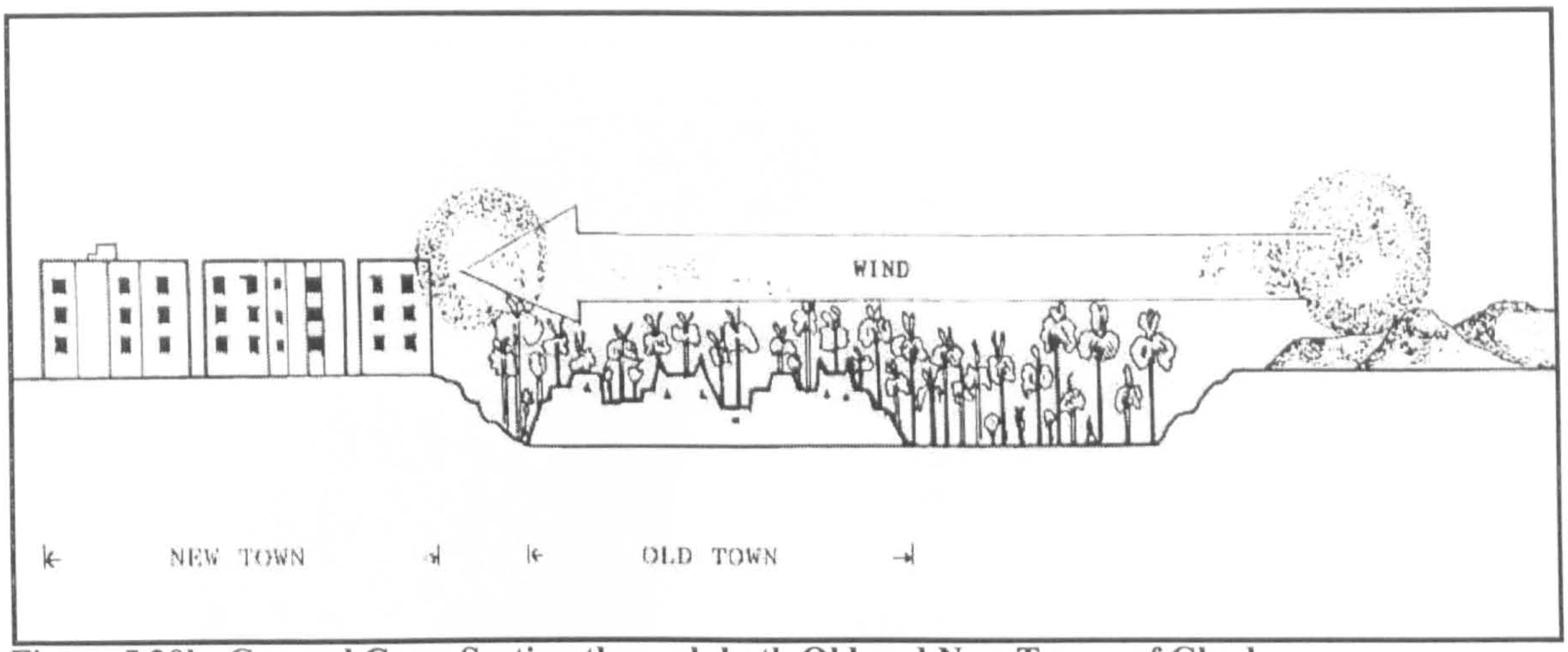


Figure 5.20b: General Cross Section through both Old and New Towns of Ghadames.

It was obvious during the field survey, in Ghadames during the summer season the surface of grass and leaves absorb radiation, and their evaporation had a cooling effect along with the generous shade and the pleasant breeze among alleyways in the old town of Ghadames. Thus, as Robinette (1972) has mentioned, plants and landforms may be used together to give even greater protection than when either element is used separately. Planting in the form of a shelter on the windward side of a hill provides a short zone of protection while the same planting on the leeward side will provide a long zone of protection for the same shelter, as shows in Figure 5.21a and Figure 5.21b.

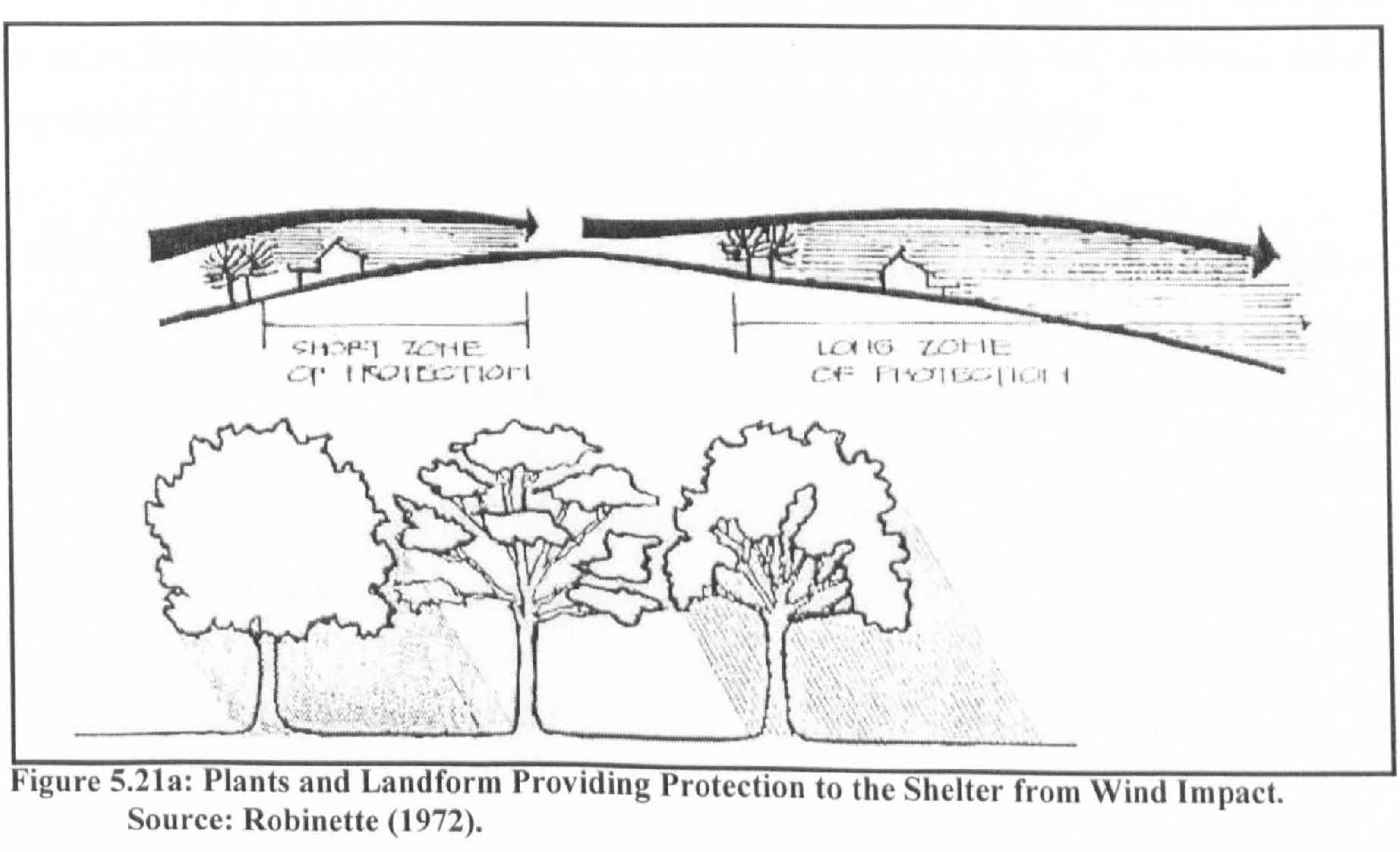


Figure 5.21a: Plants and Landform Providing Protection to the Shelter from Wind Impact. Source: Robinette (1972).

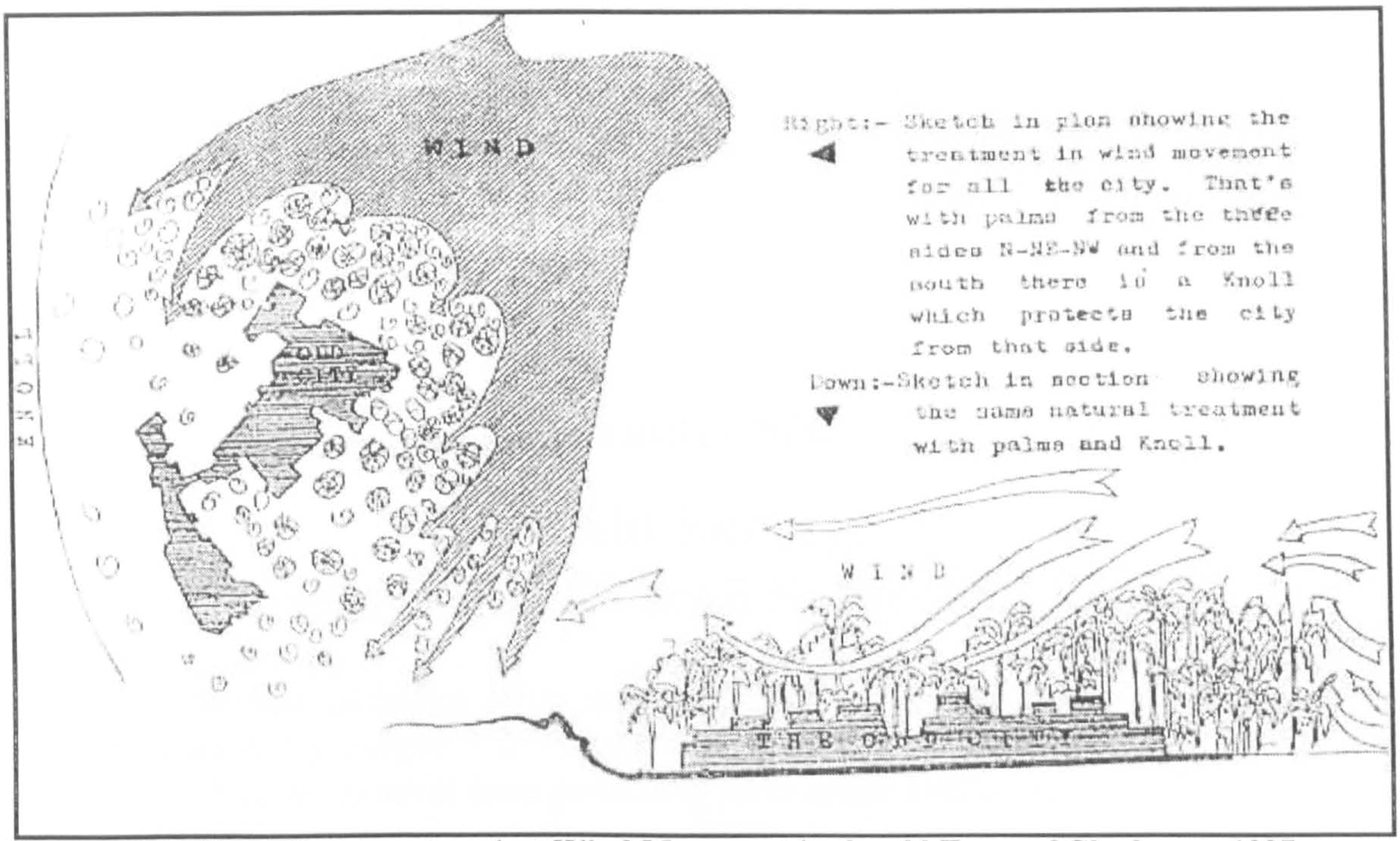


Figure 5.21b: Pants Treatment against Wind Movement in the old Town of Ghadames, 1997.

5.5 Summary

This chapter has presented the main characteristics the existing of both the old and new Ghadames towns, such as; their location and natural features, population and economic issues, social and cultural way of life, and climatic conditions. Then, it has highlighted in more detail the main architectural building forms, which are the traditional natural ventilated buildings, and the contemporary air-conditioning buildings.

Finally, it has addressed the micro-climate effects on human thermal comfort such as; wind, shadow, water and plants and vegetation. These elements form the important aspects, to be considered in future building design for such hot climatic conditions, and justify the use of both the old and new towns of Ghadames as examples. These aspects have been discussed in order to give a clear picture of the Ghadames area, so expanding the background information of chapters 2 and 3, and leading into the following chapters.

Chapter Six:

Field Survey: Procedure and Overall Subjective Results

"Scientific method, although in its more defined form, it may seem complicated, is in essence remarkably simple. It consists of observing such facts as will enable the observer to discover general laws governing facts of the kind in question."
Russel, B. (1975).

6.1 Introduction

This chapter is concerned with the conduct of the field survey, its procedure and the results that have been collected. The chapter focuses on two parts: The first part highlights the procedure of the field survey, the preparation of the questionnaire, the accuracy of the instruments, and describes the field survey, including its design and the method of selecting the building samples. The second part presents some results that have been collected during the subjective survey from the occupants in both types of buildings (i.e. old and new) by using the questionnaire. The rest of the results, which have been collected from subjective and objective surveys, will be analysed and evaluated in chapters 7, 8 and 9. The conclusions, which are relevant to the research objectives, are based on evidence that has been collected during the fieldwork in the summer seasons at Ghadames in 1997 and 1998.

6.2 Field Survey Procedure

Humphreys (1975) stated that "Field study results may be regarded as the phenomena to be explained by theoretical models of thermal comfort. Discrepancies between the predictions of the theoretical models and the observations of field studies are valuable indicators of areas where our understanding of the subject is incomplete. ... A concise statement of the principal results of field studies currently available is therefore timely". A knowledge of thermal comfort is useful for guiding the design of buildings and other enclosed environments, for achieving energy savings, and for guiding the control of environments which people cannot control for themselves. Ultimately the intention is that people should be more comfortable and healthier through improvements to their thermal environments (Raw et al, 1994).

The present field survey was carried out in 60 buildings in the Ghadames oasis, Libya in the summers of 1997 and 1998. These buildings employ natural ventilation (old traditional buildings) and mechanical ventilation systems (new buildings). Figures 6.1 and 6.2 show typical examples of these two building types. All respondents in this survey, who lived in the buildings surveyed, were belonged to Ghadamesian tribe.

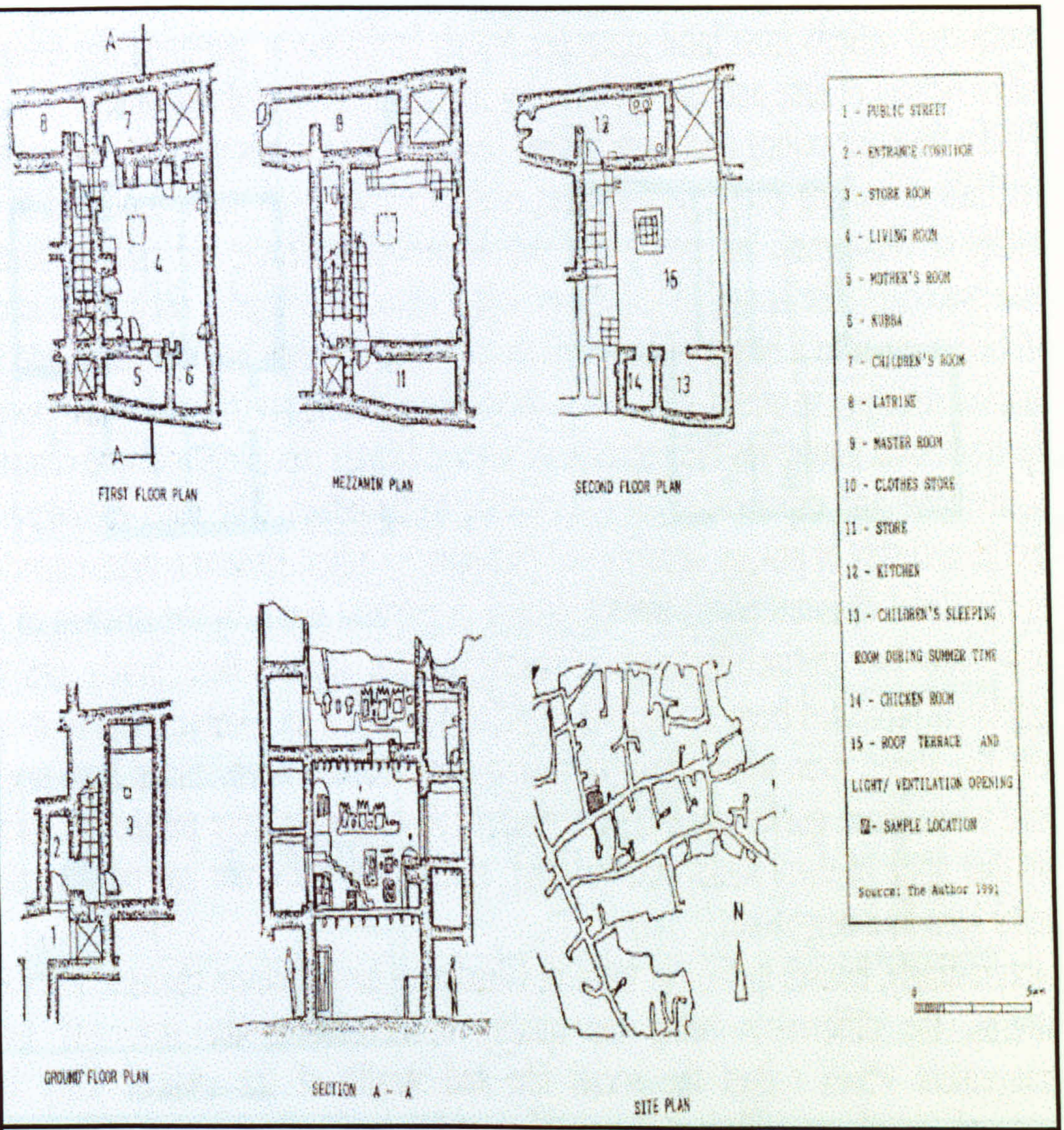


Figure 6.1:

Typical examples of traditional naturally ventilated building in old town of Ghadames, August 1997. It shown above the site map of that building, and its plan with section, while on the left the photograph shown the entrances of some buildings, at one part of the old town of Ghadames, as well as it gives general viewing example.

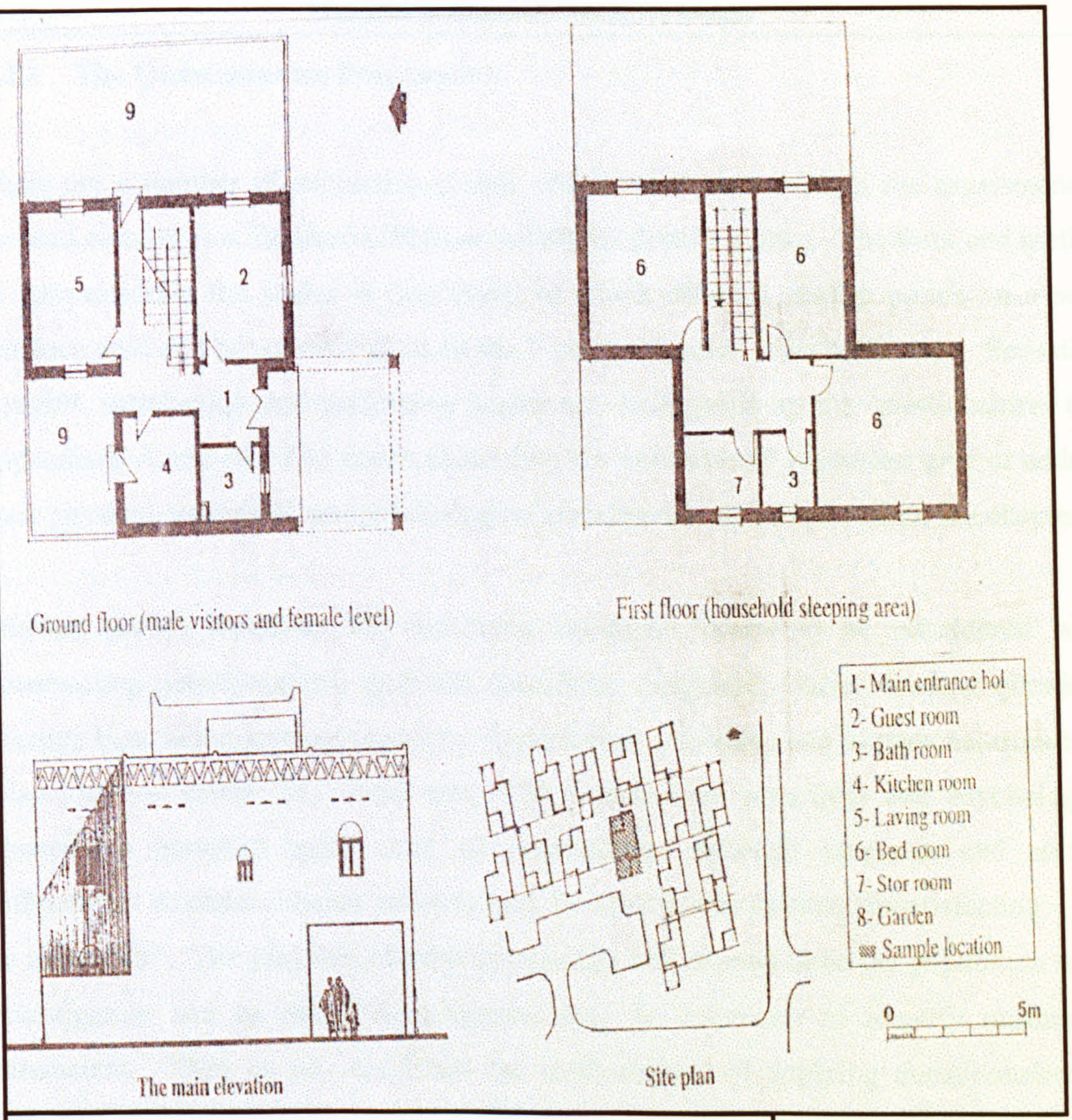


Figure 6.2:

Typical examples of contemporary air-conditioned building in new town of Ghadames, August 1997. It shown above the site map of that building, and its map with section, while on the left photograph shown different examples and viewing of new buildings which some of them are occupied and others that are still under construction, at the new town of Ghadames.

6.2.1 The Questionnaire Preparation

There are a number of subjective scales, which have been used in the assessment of thermal comfort (i.e. Bedford (1936) or ASHRAE (1966) scales). The form and method of administering the scales is important, in which subjects choose points on a scale between cold and hot or neutral, as in the 7-point sensation ASHRAE scale. Sensation, comfort, satisfaction and preference scales are determined by the questionnaires (see appendixes A and B). The scales presenting the participants' responses give or address their physical conditions and psychological phenomena. For more details see chapter 3.

Sinclair (1990) identifies the following important issues to be considered when constructing questionnaires: question specificity, language, clarity, leading questions, prestige bias, embarrassing questions, hypothetical questions and impersonal questions. Also, Parsons (1994: 82) states that "The fundamental principles and psychological phenomena however apply over all nationalities although language and cultural difference – in some cultures subjects may be reluctant to express dissatisfaction – will be important". The selection of subjective scales will depend upon the population under investigation and an initial investigation may be necessary to identify meaningful parameters. Then he has described the methodology of applying questionnaires, as follows:

> "Subjects are usually given the scale and asked to tick the place which represents '*how they feel now*', for example. It is important to avoid ambiguity which may lead to a person providing his or her own interpretation, e.g. what the environment is generally like, or how other people may perceive it, etc. ... Investigations should be emphasised that although there are many pitfalls, most can be relatively easily overcome, and the use of simple subjective methods allows easy collection of important data which can prove in the measurement of psychological responses".

ISO DIS 10551 (1993) presents the principles and methodology for the construction and use of scales for assessing the environment. Scales are in fact divided into two types; the first one is personal, and the second is environmental. The layout of questionnaire, which has been designed and used for this research project was based on the above.

It also based on other questionnaires by some researchers who are professional in this field, such as the one prepared by Parsons (1993: 81-85), and the others by Levermore, (1994: 113-118). In addition to that, questioning relating to social interactions, personal influences, people general feeling and personal well being issues have been taken from Raw (1995), in order to make this research survey valid for Ghadames.

Subjects were asked to complete a questionnaire at the same time as the environmental variables were being recorded. Details of clothing and activities were noted for each subject. For the purpose of this research project, social interactions of the residents and their personal information and occupants' thermal sensation data have been presented. These data would be included the age and gender of the subjects and his/her family; how many hours/day are spent inside the building including sleeping time; is there air-conditioning and if yes, is it operating; etc. The subjective study involved collecting data using questionnaires, which have been widely used and tested previously, for more details see Appendices A and B. The questionnaire is based on the following 6 sections: -

a) background and personal information, which covered data about the age and gender of the subjects and their families, other general information such as number hours/ day spent inside the building including sleeping time, use of mechanical ventilation, etc. All of these questions have been answered by a Yes/No response.

b) social interaction, where a 5-point scale has been used to indicate how closs in terms of distance and social relationship of the respondents to their neighbours (e.g. Too close + 1 2 3 4 5 - Too distant), aspects such as how they rely on each other and talk to one another, etc., have been indicated by a Yes/No response.

c) thermal environment and personal influences, where a 5-point scale has again been used to indicate how he/she likes the thermal environment, and the significance of factors such as the outward appearance of their building, the design of their building and the climate in general. A Yes/No response technique has been used to test whether the subject likes his/ her building in general.

d) occupants' perceptions of the environmental conditions in the whole building have been tested using a 5-point scale; taking into account noise level, natural and electric lighting, natural and mechanical ventilation, etc.

e) occupants' thermal comfort has been tested using a 4-point scale for thermal comfort, dryness, stickiness and draughtiness scales. Also, 7-point sensation, preference and satisfaction scales have been used.

f) people's general feeling and personal well being, where a Yes/No response technique has been used and tested to ascertain whether the subjects want to live in courtyard buildings or new buildings, if he/she goes outside the building between 2:00 and 5:00 PM when the outside temperature is extremely hot, is the environment acceptable to live in, etc.

At the end of each section any comments were noted. For the purpose of the present work the questionnaire was modified to include any notes or comments that might help to understand more about the environment and social life in Ghadames. This provided information which it was anticipated would help to explain any sociological reasons for people's responses to their environment (based, for example, on their culture and background). The questionnaire has been translated into the Arabic language and distributed among the residents in Ghadames oasis. The subjects were selected randomly from different groups of people in Ghadames (i.e. Educated, Administrative, Architects and Elite groups) to represent a typical range of samples. Care was taken to minimise the risks of mis-understandings arising from translations of the words describing the points on the various scales by interviewing the respondents and assisting them with completion of the questionnaires.

6.2.2 Instrumentation

The proper definition of 'accuracy of instruments' has been mentioned in ASHRAE Fundamental handbook (1997: 14.1) that "the capability of an instrument to indicate the true value of a measured quantity". The basic parameters, relevant to thermal comfort studies include; the four physical parameters; air temperature (t_a), mean radiant temperature (t_{mr}), air velocity (v_a) and vapour pressure (P_a), together with the other two personal parameters; i.e. clothing values (clo) and metabolic rate (met). The following instruments therefore were used to quantify these parameters in the experimental work:

a) Inside and outside air temperatures (t_{in} and t_{out}) were measured using radiation-shielded thermocouples (Type T, copper/constantan) located at the midle hights of each room, which are generally accurate enough for that purpose (about ± 0.2°C). These values were logged every 15 minutes and average values were calculated every hour. Commonly thermocouples and thermistors supplied with the data logger are embedded in a metallic sheath, which reduces the radiant component and shields the sensor – but it does increase its size and its thermal inertia. It has been decided to surround the thermometer with a bright metallic shield due to the strong solar radiation in Ghadames. Thus, their radiant exchange with the surrounding is relatively small. Temperatures are recorded using a data logger capable of recording a substantial amount of data for subsequent downloading into a computer. This instrument, enabled the assessment of the predicted mean vote (PMV) as presented in the ISO 7730 (1995).

b) The effects of radiant interchange were measured using a 46mm globe thermometer with accuracy about ± 0.2°C. Globe temperatures are commonly used in comfort surveys. The 46mm sphere is painted matt black and houses a thermocouple in the centre.

c) Air velocities (v_a) were measured using an omni-directional anemometer with accurate to about ± 0.5 m/s. It is necessary to measure air movement to assess thermal comfort, even though indoor velocities are often low and hence difficult to measure. It is observed by Nichol (1993: 37-38) in his thermal comfort handbook that convective air currents occur naturally around the human body, even with a sedentary subject. He has stated also that in naturally ventilated spaces, especially if these are in a hot climate, air movement will have a big effect on the thermal comfort of the subject, because of the increases of heat loss.

d) The water vapour pressure (P_a) can be measured by using a sling hygrometer. This is an instrument with two mercury thermometers in a casing, one of which has its bulb encased in a cotton wick that is soaked with distilled water (see Figure 6.3). The purpose of the wick is to obtain the 'wet bulb temperature' which enables the calculation of the water vapour pressure (P_a). The second mercury thermometer measures dry bulb temperature (t_{in}). These two bulbs are covered by the sling, which allows the thermometers to be 'whirled' in the air, in order to increase heat and moisture exchange with the air and makes radiant effects unimportant. Nichol (1993: 41) states that "in majority of surveys the humidity of the air plays relatively little part in the thermal comfort. It is still an important variable to measure, particularly in hot climates. … Water vapour pressure is that part of the total atmospheric pressure which is exerted by the water vapour in the atmosphere".

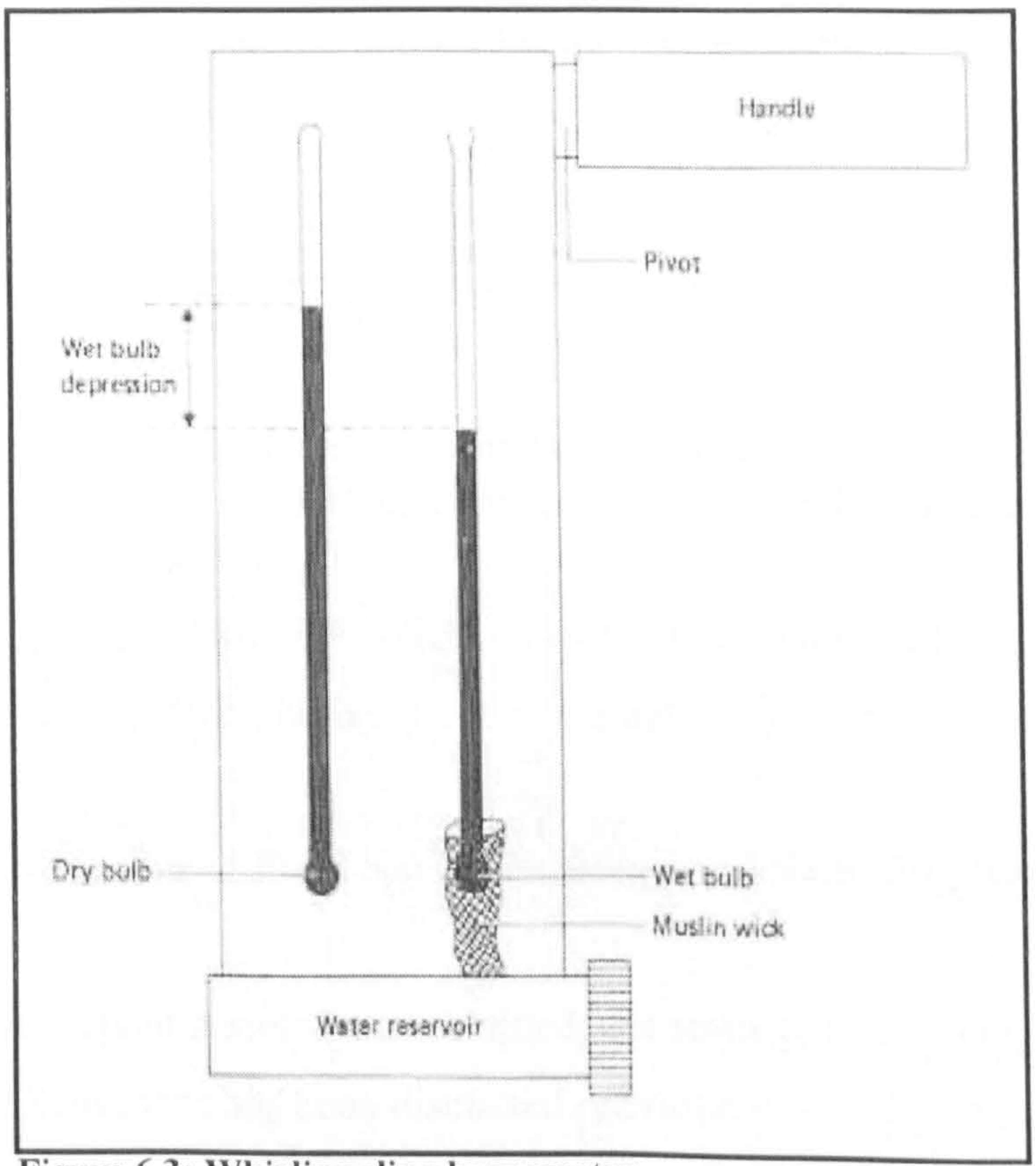


Figure 6.3: Whirling sling hygrometer.

P_a can be calculated when the water vapour saturation pressure (P_{as}) is known. The relative humidity (Rh) can then be calculated from the dry and wet bulb temperatures by using the psychromatic chart, CIBSE Guide C1 (1986), and equation (1) below.

$$\mathrm{Rh} = \frac{Pa}{Psa} \times 100 \longrightarrow (6.1)$$

e) Mean radiant temperatures (t_{mr}) were calculated by using the following equation from ISO 7726 (1994);

$$t_{mr} = [\,(t_g + 273)^4 + 2.5 \times 10^8 \times v_a{}^{0.6}\,(t_g - t_{in})\,]^{1/4} - 273 \longrightarrow (6.2)$$

where: t_{mr} is mean radiant temperature in °C; t_g is globe temperature in °C;
v_a is air velocity in m/s; and t_{in} is inside air temperature in °C.

Mean radiant temperature can also be calculated by the measuring surface temperatures of each of the six side-walls of the room and their areas, by using the following equation;

$$t_{mr} = \frac{\sum(ts \times As)}{\sum As} \longrightarrow (6.3)$$

where: t_{mr} is mean radiant temperature in °C;
ts is surface temperature in °C; and As is surface area in m^2.

McIntyre (1980) and Nichol (1993) have previously used these techniques. In this research project, both equations 6.2and 6.3 have been used.

Description of Field Survey Strategy and Sampling Design

Two sets of results were obtained; the strategy of applying questionnaires and physical measurement has been discussed previously (in chapter 4). A sample of 60 buildings (30 old and 30 new) was used for the subjective study. Of the 60 buildings, 19 (9 old; 10 new) were selected for a more thorough field survey which included the objective survey (with the measurements of environmental conditions).

The survey was carried out for both the old and new buildings in August 1997 and August 1998. The buildings selected were populated as follows:

i) For the subjective survey, the 30 old buildings contained 135 (30 × 4.5) occupants and the 30 new buildings contained 135 (30 × 4.5) occupants. This population enabled the actual mean vote (AMV) to be estimated.

ii) The combined subjective / objective surveys, involved measuring the environmental variables in 19 buildings, representing 40 (9 × 4.5) occupants in old buildings and 45 (10 × 4.5) occupants in new buildings. The collected data from this survey was used in one room that is more used by the occupants (i.e. courtyards in the old buildings, and sitting rooms in the new buildings). These data have been collected in order to calculate the predicted mean vote (PMV) of the subjects using Fanger's model as presented in ISO7730 (1995), and to calculate the neutral temperature using the adaptive model.

As mentioned before in chapter 4, traditional and modern building designs were represented in the selicted samples. Thus nine buildings were chosen from the old town according to the number of neighbourhoods. Whilst, in the new town, the ten contemporary buildings were selected according to public building types (see Figures 6.4 and 6.5).

Nichol (1993: 49) has stated, in his thermal comfort handbook for field surveys, that "It is difficult to be precise about the number of observations needed from each subject or the number of subjects we need. In general, for statistical analysis, the more data the better. ... A survey which ended up with twenty subjects each giving 100 data sets would be quite adequate. If you can get more data sets without wearing out your subjects or unduly extending the period over which the data is collected then do so".

The survey was begun by the selection of a sample to reduce the scope of field surveys to a manageable size. Attention was confined to the Ghadames oasis and focused on a small sample of 270 subjects from the 18,000 population. The investigation was directed on a comparative basis to both traditional and contemporary buildings.

A primary concern regarding the sampling process was the determination of a sufficient size for producing reliable results. Nineteen buildings (9 old and 10 new) were involved in both the subjective and objective surveys. The selection of the buildings was based on the following factors;

i) Access – due to the former political sanctions and the far distance from England to Libya. Time-scale – the study was undertaken in three weeks, therefore it was only possible to survey 19 buildings.

ii) Nature of the research – had to make prior-arrangements with local authorities in Ghadames; introduce and interview residents, and finally, select buildings whose residents agreed to participate in the survey.

iii) The difficulty of interviewing females for a male researcher, due to the religion of the people and their social and cultural way of life.

iv) The desire to give more opportunity to all family members to participate in answering the questions. Moreover, the side talk which usually takes place during the filling in of the questionnaire is of great importance, simply because it reveals some aspects that may not be covered by the questionnaire.

All of these issues together with the usually technical and logistic problems of site-work limited the sample size to make the survey possible. Nevertheless the sample was selected in such a way that a reasonable cross section of buildings was involved. Also, one of the most important facts, when conducting this kind of field survey, was to provide the physical context for the more detailed information obtained about buildings and their occupants' behaviour. During the site work the researcher acquired an integrated picture of the behaviour of the residents and their daily life in both types of buildings (traditional NV and contemporary AC). This assisted in the understanding and interpretation in some of the attitudes and responses of occupants obtained in the field survey.

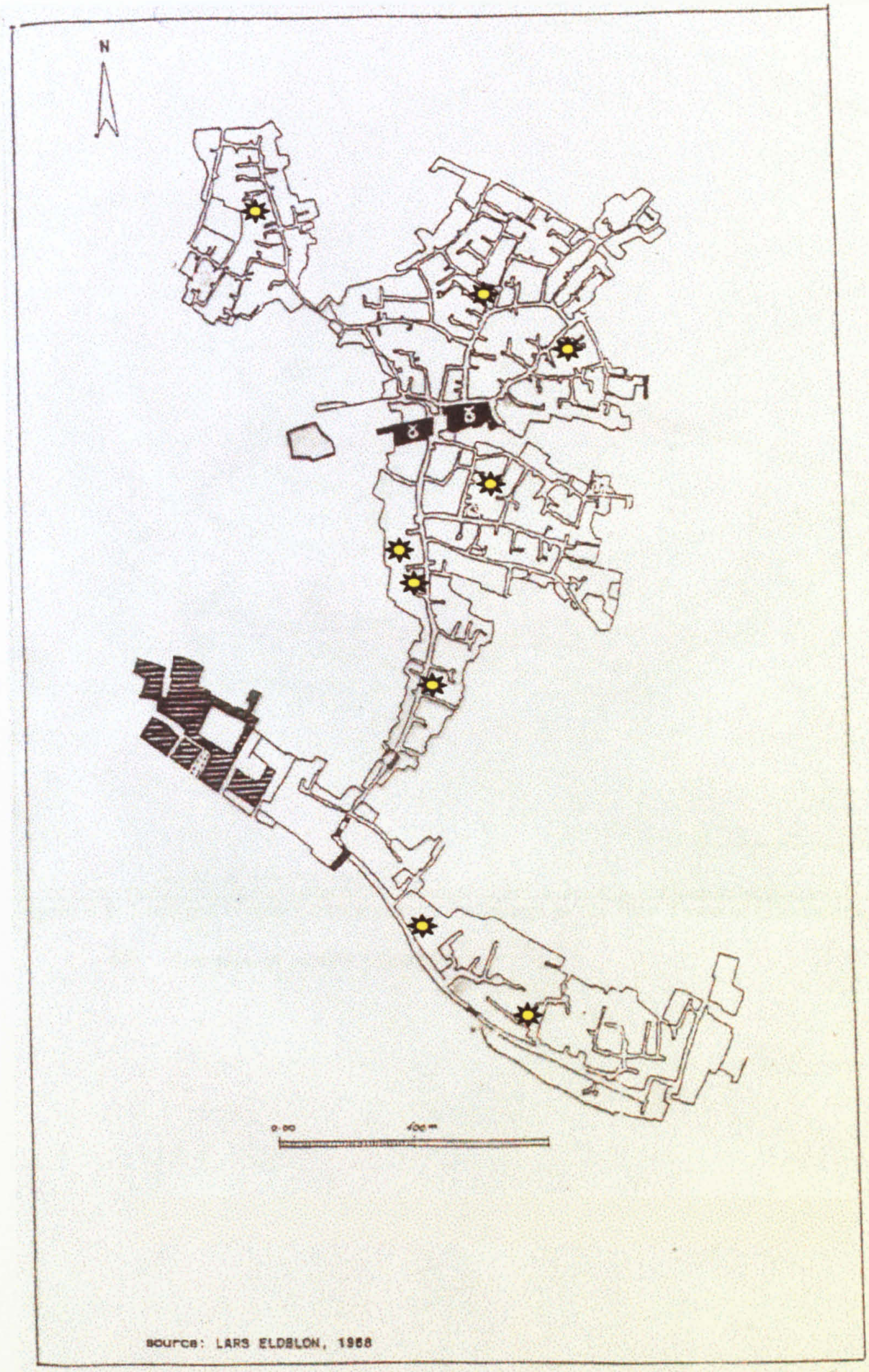


Figure 6.4: Location of Nine Traditional Buildings in the Old Town of Ghadames, 1997.

✵ Location of sample selected

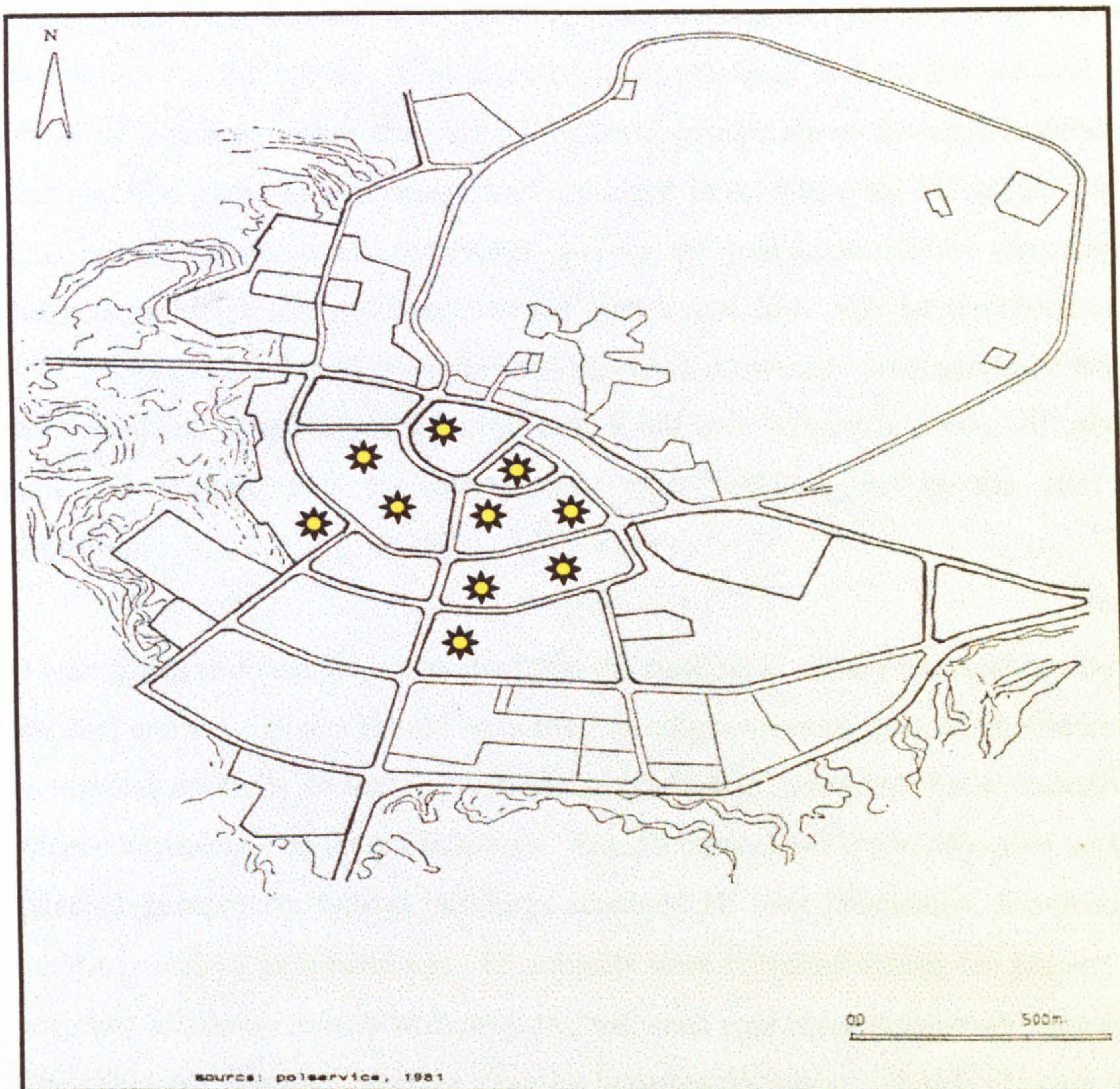


Figure 6.5: Location of Ten Contemporary Buildings in the New Town of Ghadames, 1997.

Location of sample selected

The Author first liaised with the local Authorities of Ghadames to obtain their permission for the survey. The selected local residents in both the old and the new towns of Ghadames were then briefed in small groups about the experimental project. Each section of the questionnaire was explained in readiness for the subjective survey. The questionnaires were distributed among 60 buildings, which represented 270 subjects (participants), and then returned after a few days. All the questionnaires were checked to ensure that all the questions had been answered. Arrangements were made with residents of the selected samples of 9 old and 10 new buildings to conduct the objective survey, and the instruments were installed before the start of the measurements.

It was however considered important that the conditions should be measured throughout the day, and the subjects should be in their familiar environments and should be allowed to respond normally so that the environment which is measured is representative of the normal experience of the participants. The 19 buildings for the objective survey were selected to represent typical buildings scattered all over Ghadames, comprising 9 old buildings and 10 new buildings. 85 subjects were recruited during the project, together with two assistants to help with preparations, such care management and measurements. The subjects males and females, ranging between the age of 20 and 50 years, took part in the experiment. All selected buildings and occupants were considered to be representative of the town and population of Ghadames for the following reasons:

a) Building related factors; each type of building was similar in location (in old and new town) shape, design, neighbourhood, etc.
b) Social factors; they were selected at the same socio-economic characteristics that are unified by the Muslim Faith, e.g. tribe, trend, religion, clothing, etc.

Subjects were allowed to carry out their typical activities for periods of two hours in three different sessions, during the day of experimentation, between 8am to 10pm. The three sessions were selected at 10am, 2pm and 8pm. All the basic environmental parameters such as air temperature, globe temperature, surface temperature, air velocity and relative humidity, as well as the outside air temperature were recorded for one week for each building, in three times a day: morning (8-10 AM), afternoon (2-4 PM) and night (8-10 PM), see Appendix E. The respondents in this field study continued their normal occupations daily activities of the population in Ghadames. None of the respondents were involved with any heavy work inside their buildings. The experiments were carried out for each building over seven days (20-26 July 1998).

The main body of the data was collected during the day time (i.e. 2-4 PM), when the indoor air temperatures would have been above the indoor daily mean, and the overall average outside air temperature was substantially higher than the mean inside air temperature. The four physical and two personal parameters were logged every 15 minutes and average values were calculated every hour. Air velocities and mean globe temperatures were measured, and mean radiant temperatures were then calculated. From the reading of these instruments together with the estimation of personal factors, the current thermal comfort indices can be tested, as will be discussed and analysed in the following chapter (7). Subjects had completed the questionnaire about their comfort and sensation levels AMV (i.e. how they feel now?) by the end of each two-hour session.

Figures 6.6 shows a typical example of the courtyard in the traditional building and the one occupant wearing typical traditional clothes, while Figure 6.7 shows some subjects seated during the day time on benches in shaded area in the old town. Figures 6.8 and 6.9 show typical examples of participants who were seated on the floor in the courtyard for the traditional NV building, and in the sitting room for the contemporary AC building. They are among the selected subjects and are completing the questionnaires during the experimental work.

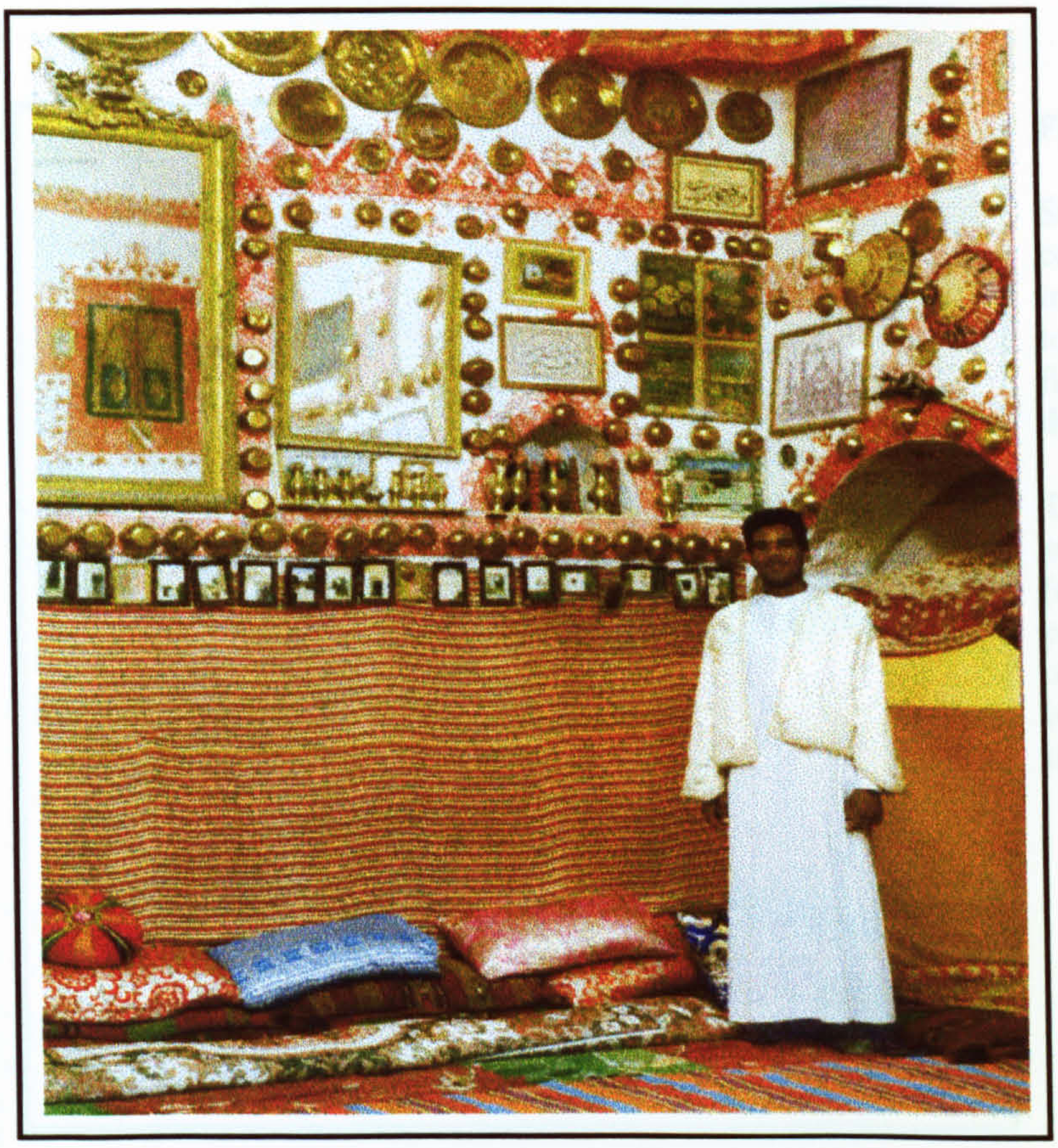


Figure 6.6:

Interior view of the courtyard in an old building, showing the occupant wearing typical traditional clothes.

The figure shows also that the interior walls of the courtyard are fully decorated, and the occupants usually putting mirrors which help to reflect the light into the surrounding rooms and the rooms below.

Figure 6.7:

Subjects seated on benches in shaded area at the public square in the old town of Ghadames, showing them wearing typical traditional summer clothes.

The figure shows that they were seated during the day time very relaxed despite the sever outdoor climate.

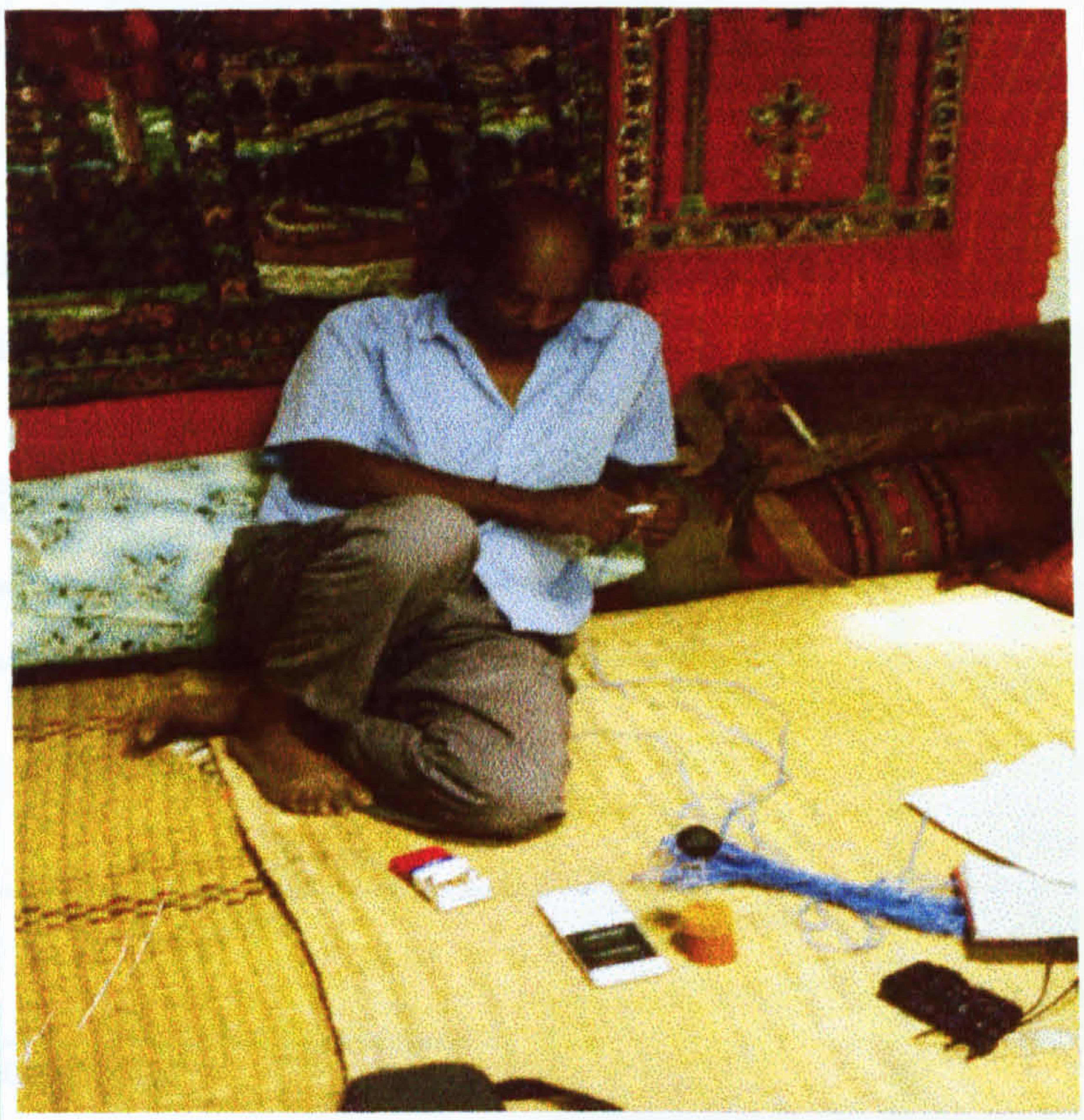


Figure 6.8:

Subject set on the floor in courtyard inside his traditional NV building, at old town of Ghadames, after filling in the questionnaire during the experimental work.

The figure shows also that the subject is in his normal attire (clothes) and in his relax position. It shows also some of the instruments, such as the black globe thermometer and the whirling sling hygrometer.

Figure 6.9:

Subject set on the floor at sitting room inside his contemporary AC building, at new town of Ghadames, and filling the questionnaire during the experimental work.

The figure shows also that the subject is in his normal attire (clothes) and in his relax position. It shows also some of the instruments, such as the black globe thermometer and the whirling sling hygrometer

6.3 Overall Subjective Results

A full set of results is presented in Appendix D. A summary of the personal information from the respondents is shown in Table 6.1. The same results of this subjective survey using these respondents are described in the following sections.

Table 6.1: Summary of personal information of the respondents.

Total number of building	= 60	Old Building	New Building
Sample		30 buildings	30 buildings
People and Gender/ household	a) Average Size	4.5 person/ building	4.5 person
	b) Male	5.0 person/ building	3.4 person
	c) Female	4 person/ building	5.5 person
Age	a) Adult (19-70)	4.5 person/ building	4.5 person
	b) Children (0-18)	7.9 person/ building	2.7 person
Occupancy	Owner (%)	96	96
	Tenant (%)	4	4

6.3.1 Traditional Buildings vs. Contemporary Buildings

Figure 6.10 shows the comparison of AMV between 30 old buildings and 30 new buildings represent the occupants' overall votes during the whole summer season (i.e. AC on and off). It shows that 47% of respondents, regarding their overall view of their traditional NV buildings, reported their neutrality (0) compared to only 30% having the equivalent overall view of their contemporary AC buildings. It also shows that 6% reported being hot (+3) in the traditional NV buildings compared with 30% in the contemporary AC buildings. It should be noted that for these tests, the AC unit were turned off, in order to test the thermal performance of both types of buildings and the human adaptation, as will be described in more detail in the following chapter (7). There were only 15% who felt slightly warm (+1) in traditional buildings, comparing with 24% in the contemporary buildings. While, 6% of people felt warm (+2) in both types of buildings. In addition, 26% of participants reported as being slightly cool (-1) in the traditional NV buildings compared with 6% in the new buildings, and non of them reported cool (-2) or cold (-3) in both types of buildings (i.e. their responded were 0%).

Furthermore, the subjective survey results of the occupants' votes about their satisfaction, comfort and preference levels during the whole summer season, as illustrated in Figure 6.11. The figure shown that in the case of the traditional NV buildings, the occupants reporting on the 'comfort scale'; 85% of them were satisfied and happy, while only 15% were uncomfortable. At the same time, on the 'satisfaction scale', there were 80% of the occupants who reported to be satisfied with the quality of their indoor climate, and therefore the majority (70%) of them they requested no change to be made on their indoor climate level.

On the other hand, Figure 6.11 illustrated also that in the case of the contemporary AC buildings, the occupants reported on the 'comfort scale' 50% of them were satisfied and happy, while 50% were uncomfortable. At the same time, on the 'satisfaction scale', there were 35% of the occupants who reported to be satisfied with the quality achievement of their indoor climate. Therefore the majority (60%) of them implied that a change into cooler should be made by reducing the temperature of their indoor space.

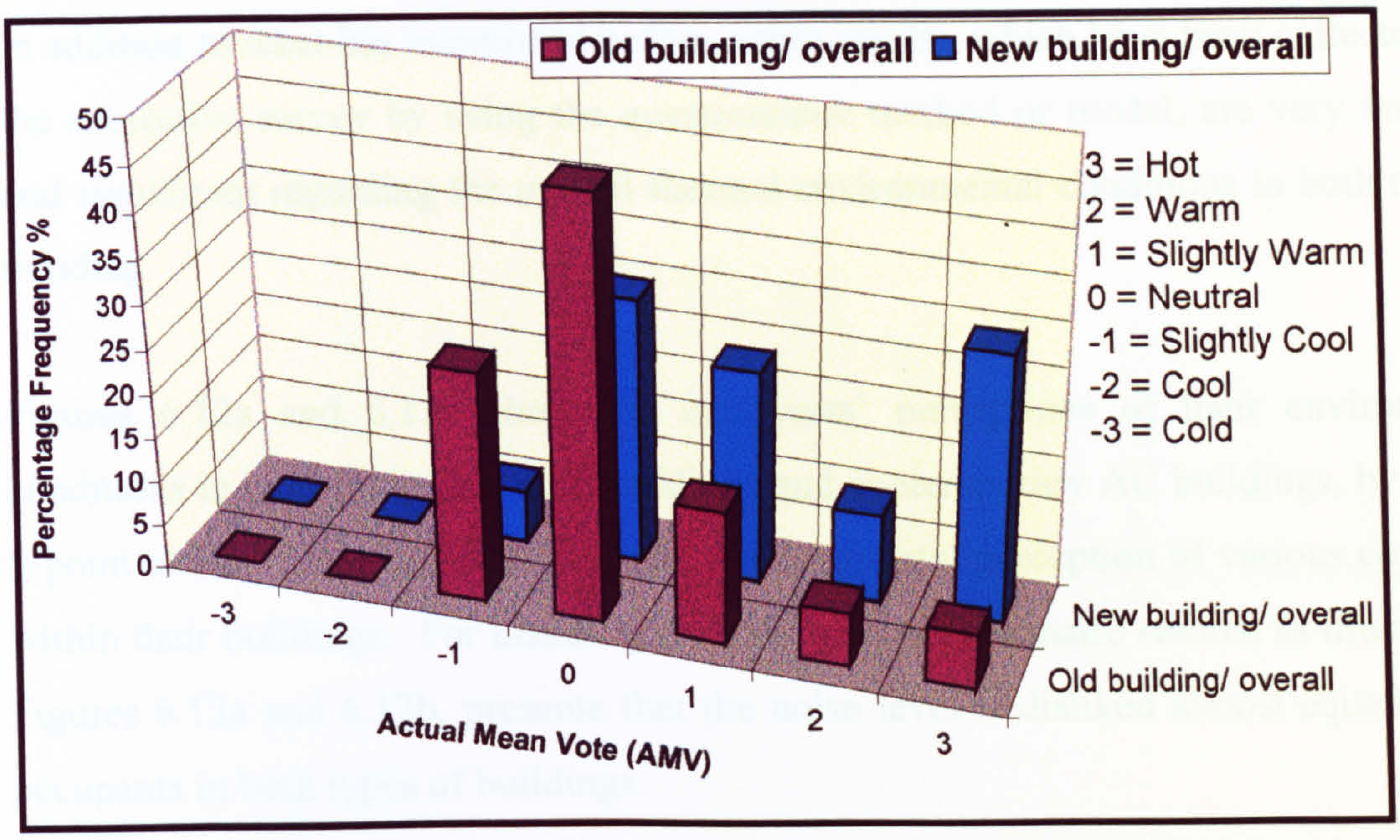


Figure 6.10: Comparison of the AMV for the traditional NV buildings with the contemporary AC buildings, Ghadames oasis, 1997.

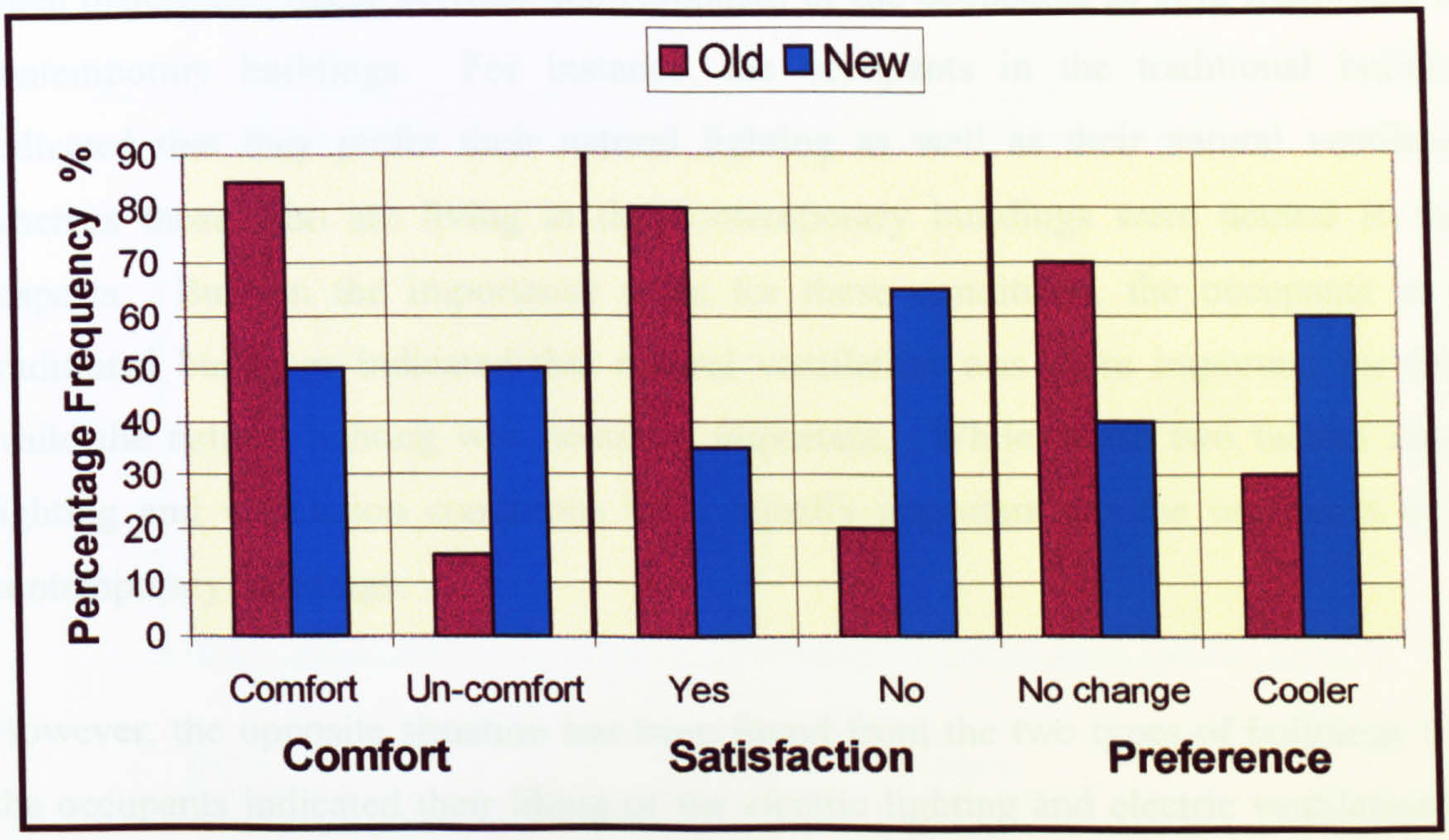


Figure 6.11: Comparison of the Comfort, Satisfaction and Preference scales for the traditional NV buildings with the contemporary AC buildings, Ghadames oasis, 1997.

In addition to what has mentioned before, other results, which have been collected from the subjective survey by using the questionnaire method or model, are very important and significant regarding the overall thermal environmental conditions in both types of building.

Figures 6.12a and 6.12b show the occupants' perceptions of their environmental conditions in both traditional NV buildings and contemporary AC buildings, by using a 5-point scale. These results to indicate the occupants' perception of various conditions within their buildings. For instance, the collected questionnaire results, as illustrated in Figures 6.12a and 6.12b, presente that the noise level is disliked almost equally by all occupants in both types of buildings.

The most significant results, as illustrated in the above mentioned two figures, appear when differences occur between the responses of the occupants in both traditional and contemporary buildings. For instance, the occupants in the traditional buildings indicated that they prefer their natural lighting as well as their natural ventilation, whereas those who are living in the contemporary buildings were neutral in these respects. But, on the importance scale for these conditions, the occupants in the traditional buildings indicated that natural ventilation was more important for them, while the natural lighting was neutrally important. While, these two factors natural lighting and ventilation conditions were equally important for the occupants in the contemporary buildings.

However, the opposite situation has been found from the two types of buildings when the occupants indicated their liking of the electric lighting and electric ventilation (i.e. air conditioning unites AC). But, these two conditions were more important for the occupants who lived in the contemporary buildings than the other occupants who lived in the traditional buildings. In fact, the same differences have been found about their liking and important levels of air movement, room temperature (i.e. courtyard for traditional buildings, and sitting room for contemporary buildings), and also the humidity condition.

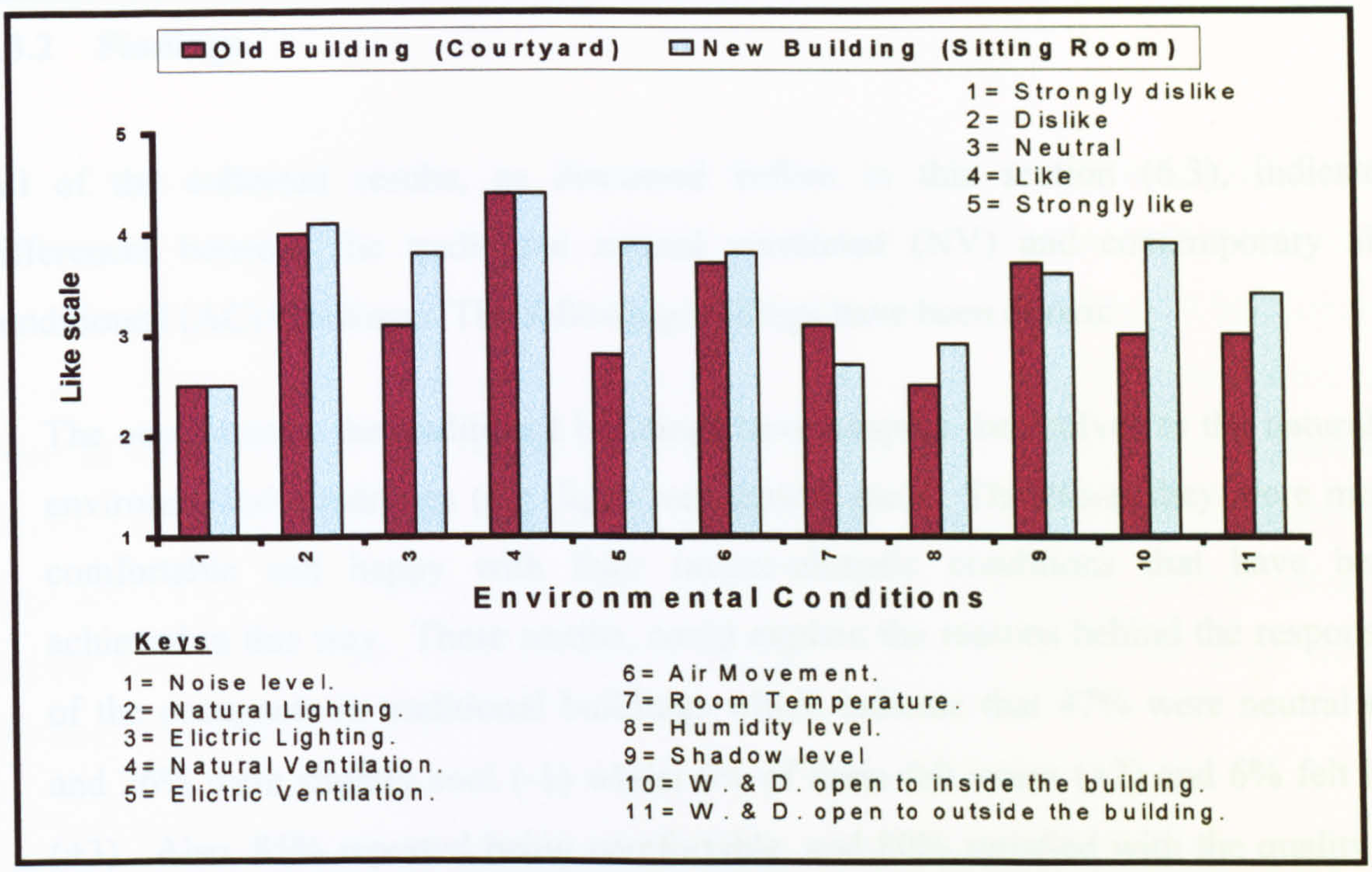


Figure 6.12a: Like - Environmental Conditions Votes between the Old Building (Courtyard) and the New building (Sitting room), Ghadames, August 1997.

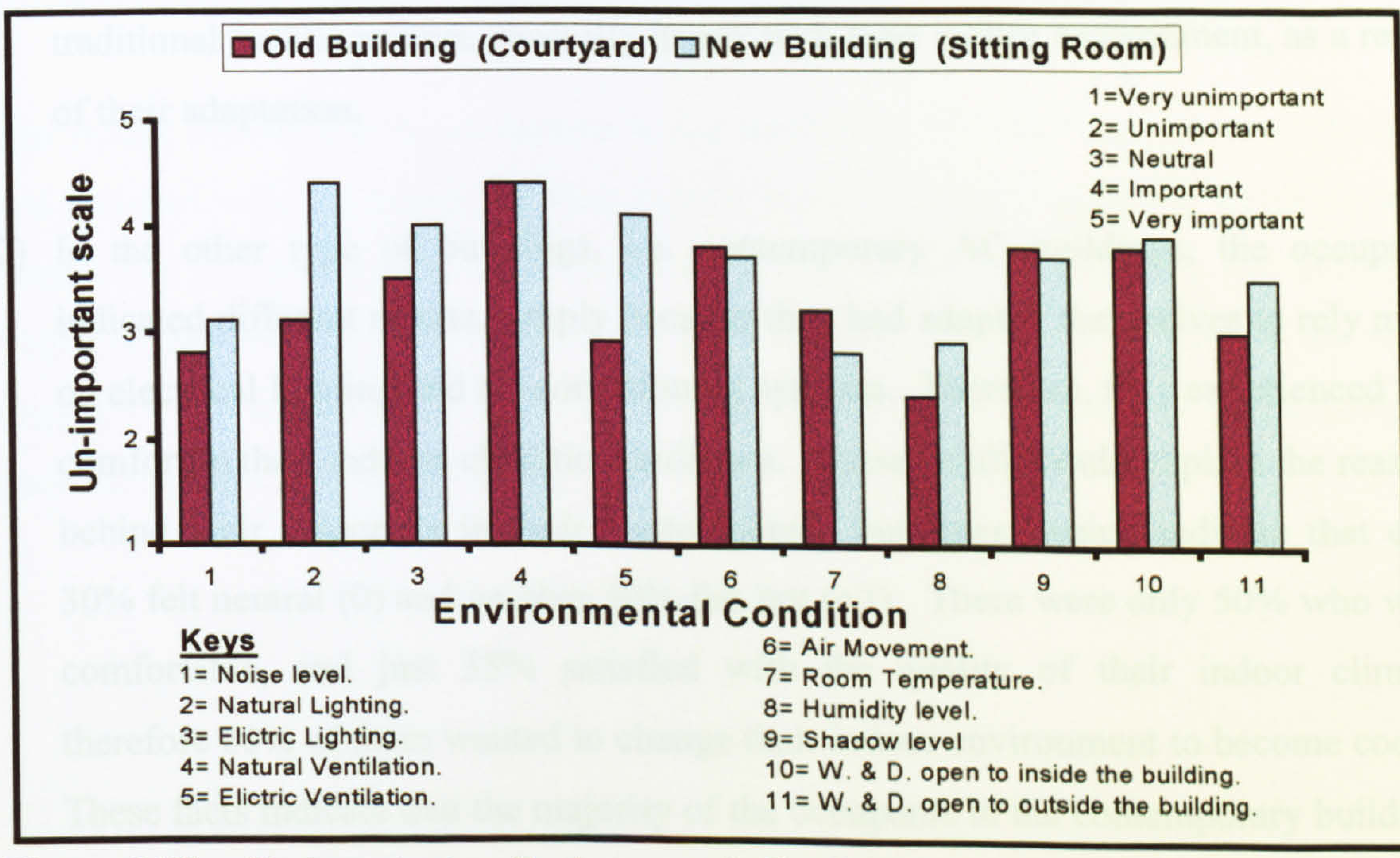


Figure 6.12b.: Un-improtant - Environmental Conditions votes between the Old Building (Courtyard) and the New Building (Sitting room), Ghadames, August 1997.

6.3.2 Findings

All of the collected results, as discussed before in this section (6.3), indicated differences between the traditional natural ventilated (NV) and contemporary air-conditioned (AC) buildings. The following findings have been drawn:

1) The occupants in the traditional buildings have adapted themselves to the naturally environmental conditions (e.g. light, ventilation, etc.). Therefore, they were more comfortable and happy with their indoor-climatic conditions that have been achieved in this way. These results, could explain the reasons behind the responses of the occupants in traditional buildings which indicate that 47% were neutral (0) and 26% were slightly cool (-1) whilst 6% of them felt warm (+2) and 6% felt hot (+3). Also, 85% reported being comfortable, and 80% satisfied with the quality of their indoor climate; therefore 70% of them wanted no change of their indoor environment. These results indicated that the majority of the respondents in the traditional buildings were generally happy with their indoor environment, as a result of their adaptation.

2) In the other type of buildings, i.e. contemporary AC buildings, the occupants indicated different results, simply because they had adapted themselves to rely more on electrical lighting and air-conditioning systems. Therefore, they experienced less comfort in their indoors climatic conditions. These results could explain the reasons behind their responses in their contemporary buildings, which indicate that only 30% felt neutral (0) and another 30% felt hot (+3). There were only 50% who were comfortable, and just 35% satisfied with the quality of their indoor climate; therefore 60% of them wanted to change their indoor environment to become cooler. These facts indicate that the majority of the occupants in the contemporary buildings were not so happy, and that may be because they have adapted themselves to rely on air conditioning, which had then been turned off for the tests.

These differences will be discussed in more detail in the following chapters (7, 8 and 9).

6.4 Summary

This chapter has been divided into two main sections. The first section has focused on addressing the procedure that has been taken to conduct the field surveys (i.e. subjective and objective) during summer the 1997 and 1998 seasons in Ghadames. It highlighted, at the beginning, the questionnaire preparation technique, and then described the instruments that have been used during the experimental work. It has also described the field survey in terms of its design and sample selection for both NV and AC buildings. This section has been presented in this chapter in order to link the present collected results with the previous information in chapters 1 and 4, where the field survey methodology was introduced.

In the second section of this chapter, some of the subjective results from the questionnaires have been presented. This preliminary analysis is based only on the occupants' reported results of their overall actual mean vote (AMV).

The results proved that the occupants in the traditional NV buildings were comfortable and satisfied with the quality of their overall indoor climate during the whole summer season and compared with those who were living in the contemporary AC buildings. These results will be used as bases for the following chapters (7, 8 and 9), in which Fanger's PMV model and the adaptive model will be tested as methods of assessing the thermal comfort in such environments.

Chapter Seven:

Data Analysis and Interpretation: Assessing Thermal Comfort

"Here almost for the first time, was an architecture in which environmental technology was not called in as a desperate remedy, nor had it dictated the forms of the structure, but was finally and naturally subsumed into the normal working methods of the architect, and contributed to his freedom of design". Banham, R. (1969: p111).

7.1 Introduction

The main purposes of this chapter is to analyses and evaluate the available data that have been collected from both traditional architectural design buildings with natural ventilation (NV) and the modern architectural design buildings with air conditioning (AC). All the measurements for thermal comfort requirements have been collected in the form of subjective data and objective data (as highlighted earlier in the previous chapter 6). Then the next stage will be the analysis and evaluation of these results in this chapter, which discusses the practical application of two main thermal comfort models:

a) ISO 7730 Standards, as set by Fanger's thermal comfort model (ISO 7730, 1995).

b) Adaptive model.

As mentioned in chapter three, the thermal comfort standards prescribed by ISO 7730 (1995) are the first that have been used on a world-wide basis. They are based on Fanger's work in climate chamber experiments on young Danish students that has led to the PMV model which is applicable to both naturally ventilated and air-conditioned buildings. The adaptive approach is based on the fact that there is a range of actions that a human being can and does take in order to achieve thermal comfort. It is taking in its consideration both:

a) the same six basic parameters (i.e. four physical and two personal) as the PMV model, and
b) outside air temperature together with the human social aspects that influence their personal acclimatisation.

The questions are whether current models used to establish comfort conditions are appropriate for people who live in a hot-dry climate, and the extent to which deviations from comfort conditions affect the degree of discomfort of people in such environments.

This chapter seeks to determine the extent to which existing research findings; and the ISO 7730 standard which is based on the Fanger PMV model (Fanger, 1970) or the adaptive model (Humphreys 1976, Auliecims 1983, and de Dear et al 1998), could be applied when designing for thermal comfort in hot-dry climates.

7.2 Discussion of Results and Findings

The subjective and objective studies were carried out in 19 buildings (9 old and10 new) at the same time, in order to measured the basic environmental parameters, which were used to calculate the PMV values and the neutral temperatures of the subjects. Data from the questionnaires were used to determine the AMV of the subjects. The procedure was described in the previous chapter (field survey, section 6.2). However, the measurements in the contemporary AC buildings were carried out for two cases;

1) When AC units were in operation.

2) When AC units were turned off. This helps to;
    - assess building performance for different conditions,
    - test the adaptation effects on the human comfort over sensation scale, and
    - compare the human thermal sensation by indicating their AMV within different ranges of temperatures for the occupants when AC on and off.

7.2.1 Building Performance

For instance, Figure 7.1a illustrates that the maximum difference between inside air temperature and outside air temperature for the traditional buildings, is equal 18°C. This difference varies according to location of each room (e.g. kitchen at the roof of the building, courtyard at the first and second floor and the entrance and storeroom at the ground floor). When the outdoor air temperature was 46°C, the indoor air temperature in the storeroom was measured to be 28°C. While, Figure 7.1b illustrates that the outdoor air temperature was as well equal 46°C and indoor air temperature in the kitchen and store was equal 36°C in the new buildings, so the difference of air temperature is equal 10°C.

A variety of thermal indoor temperature gradients which exist vertically within the traditional buildings more than that which is exist vertically within the contemporary buildings, i.e. 8°C difference.

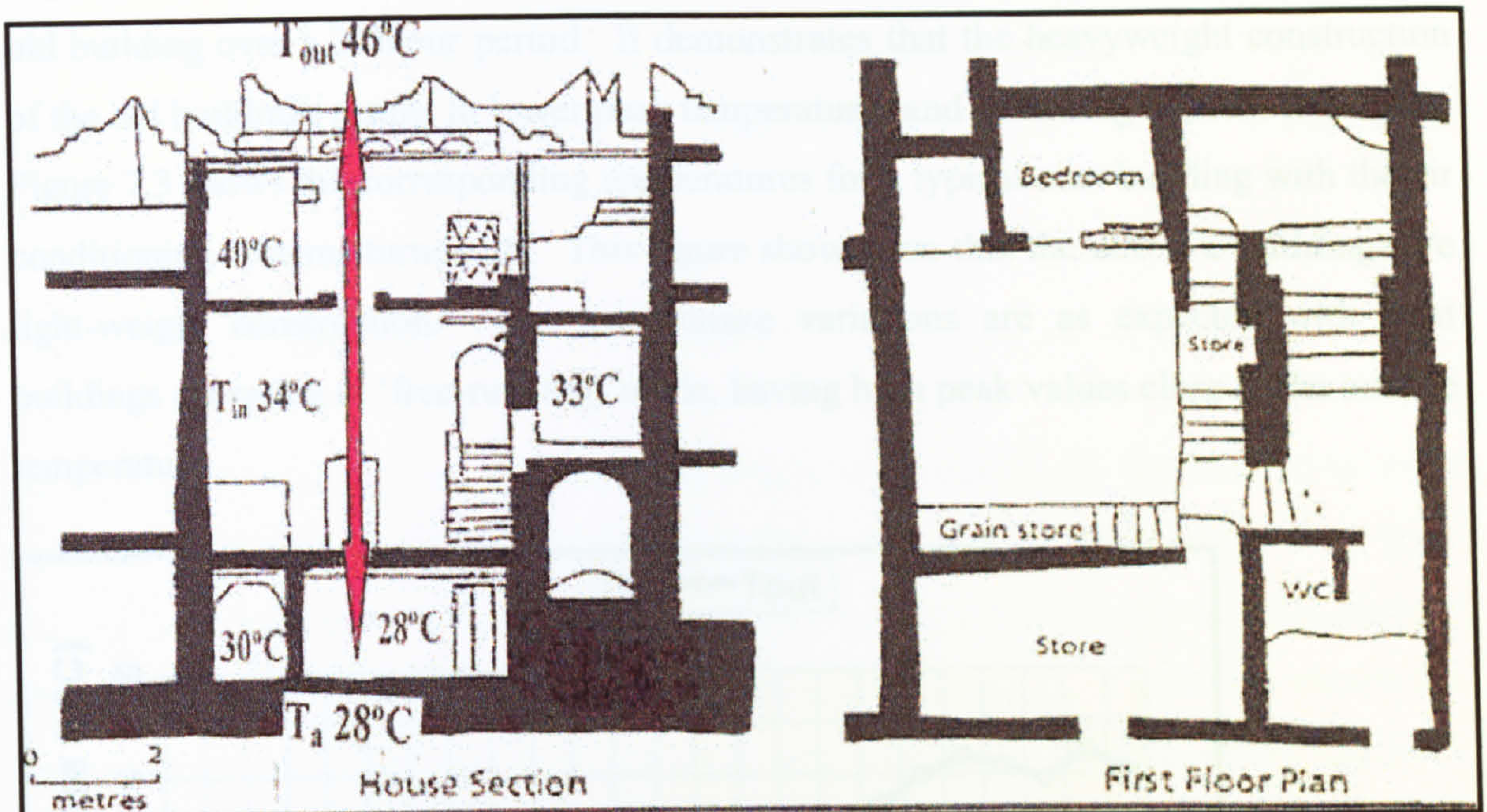


Figure 7.1a: Temperature gradients that exist vertically within a traditional building in Ghadames.

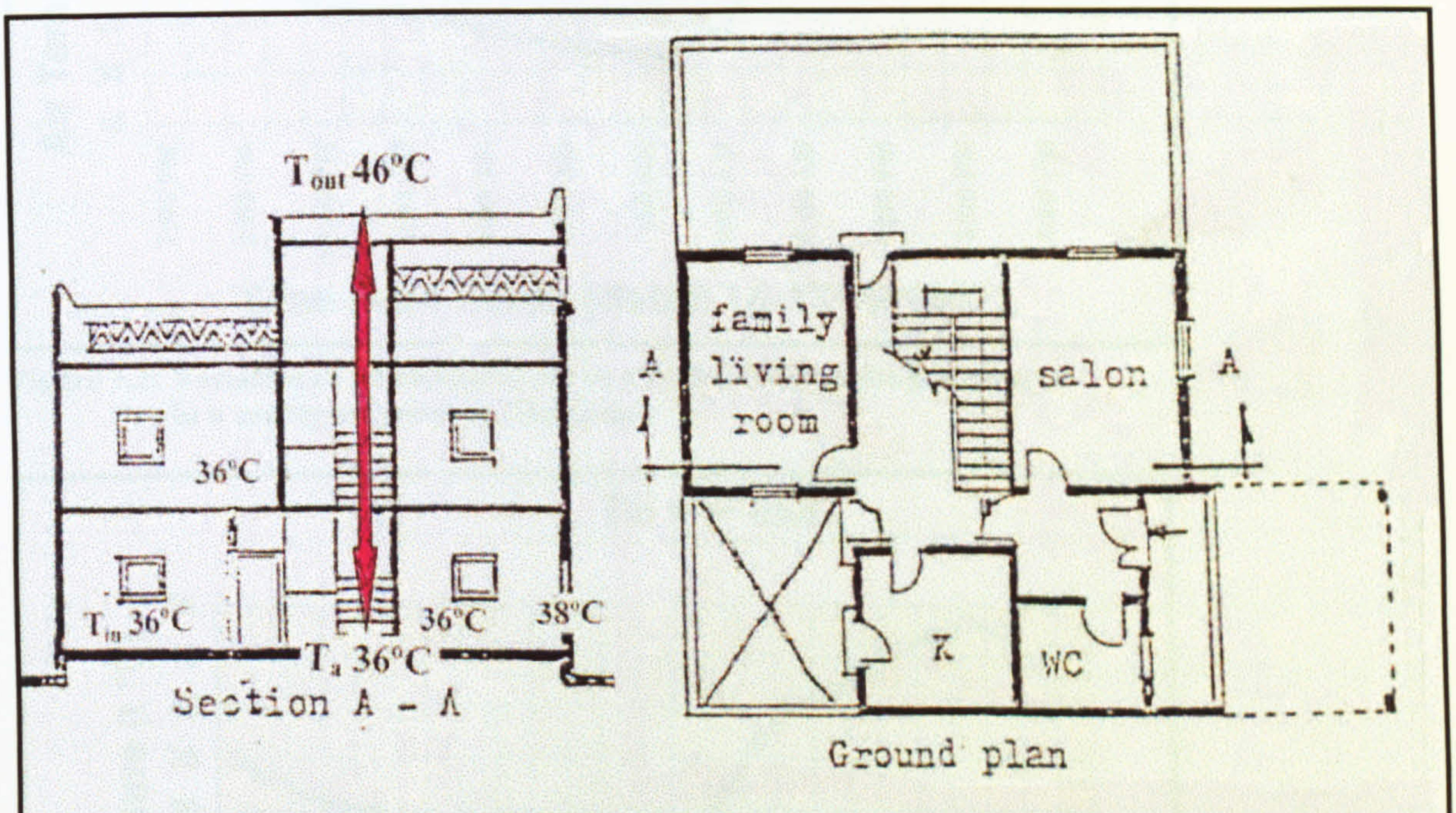


Figure 7.1b: Temperature gradients that exist vertically within a contemporary building in Ghadames, when AC was turned off.

Figure 7.2 illustrates the distribution of inside and outside air temperatures for a typical old building over a 24-hour period. It demonstrates that the heavyweight construction of the old buildings results in lower peak temperatures and a time lag of some 2-3 hours. Figure 7.3 shows the corresponding temperatures for a typical new building with the air conditioning systems turned off. This figure shows also that the new AC buildings are light-weight construction. The temperature variations are as expected with light buildings operating in 'free-running' mode, having high peak values close to the outside temperature.

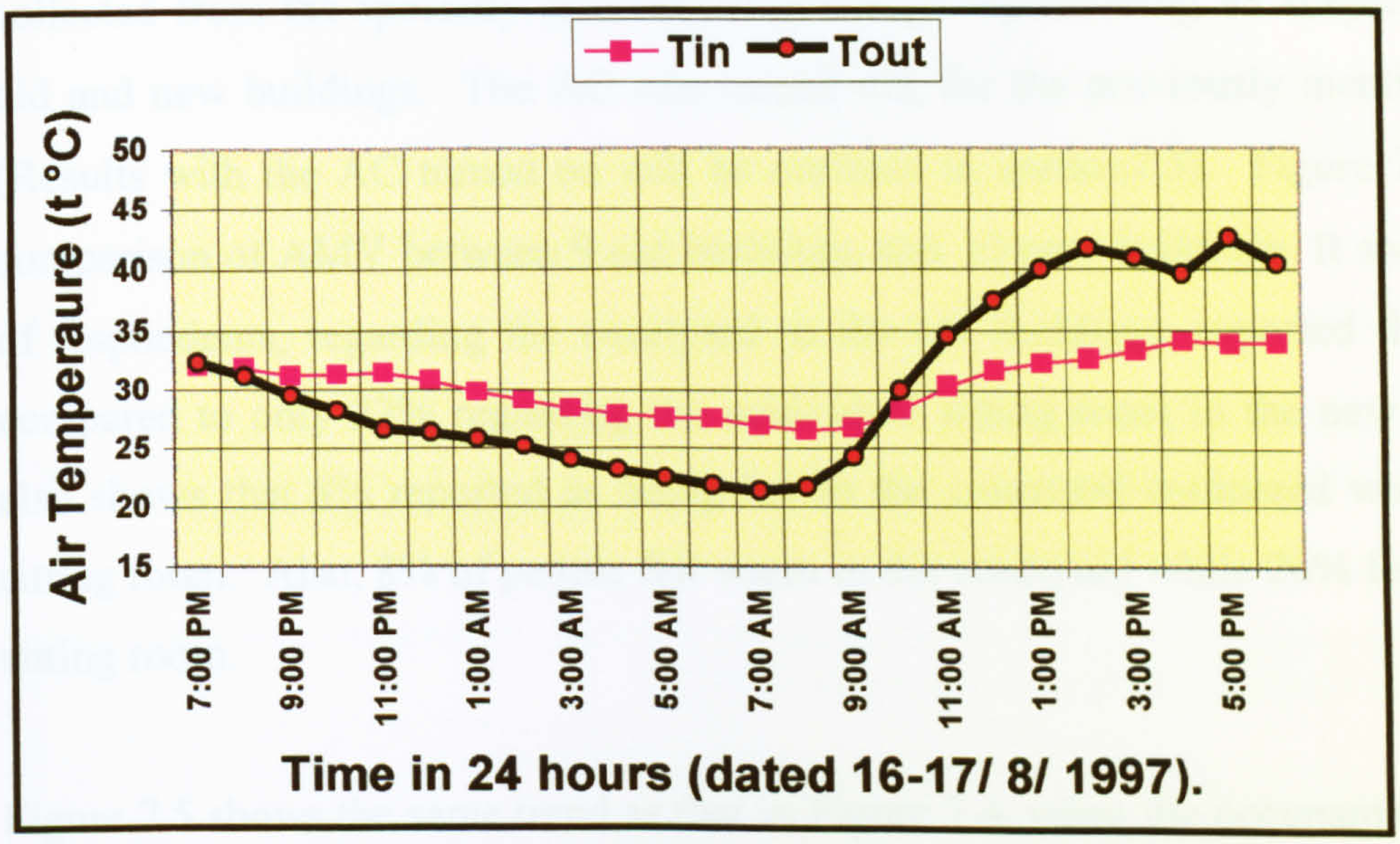


Figure 7.2: Variation of air temperature in a typical old building measured in a courtyard room at Ghadames.

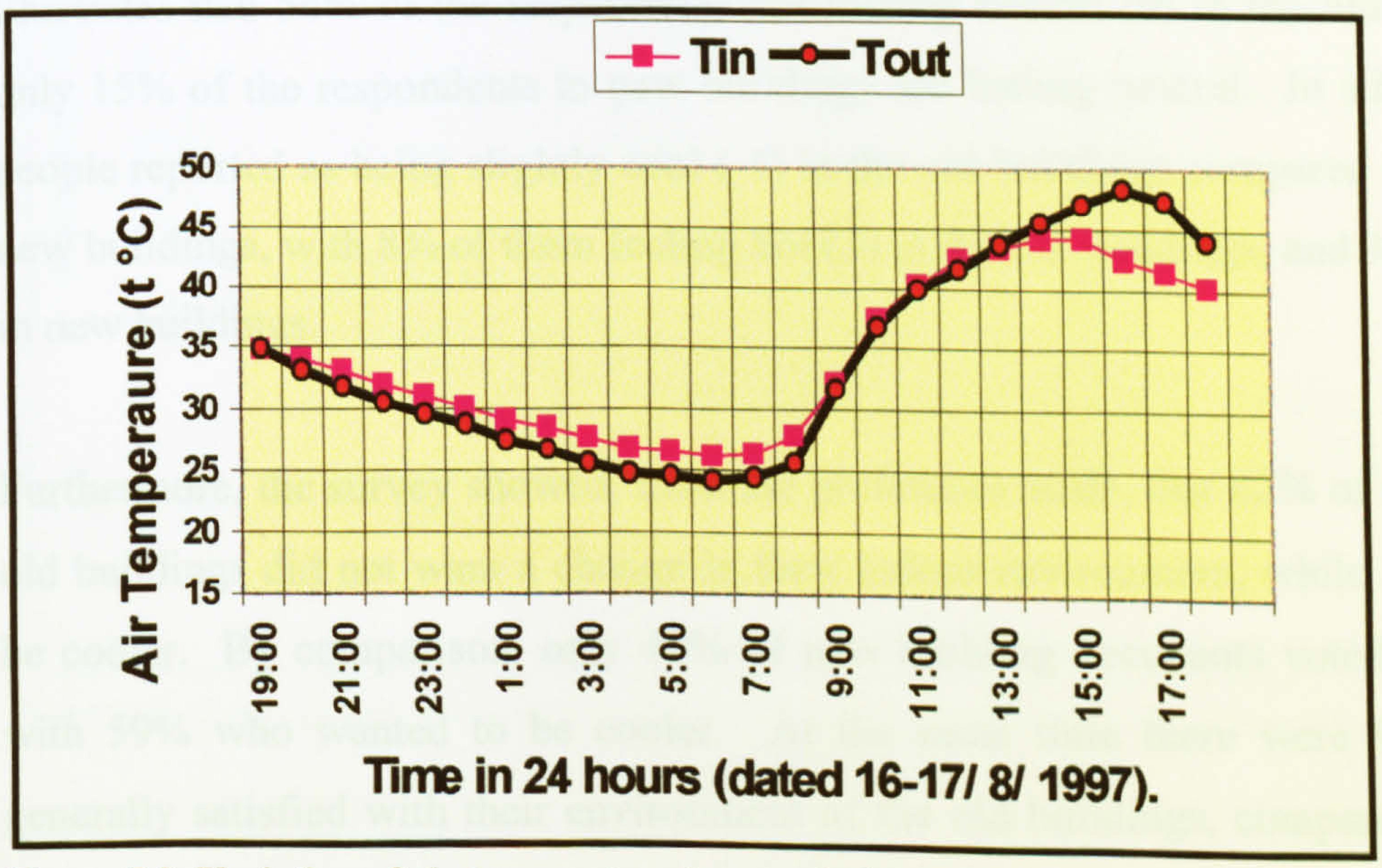


Figure 7.3: Variation of air temperature in a typical new building measured in a sitting room at Ghadames.

The experimental results show clearly that the traditional architectural design could provide a better indoor environment for residents than the contemporary architectural designs.

7.2.2 Actual Mean Vote (AMV) of Subjects

For combined results of the objective and subjective surveys, the questionnaires were collected from the specially selected 19 buildings representing 85 subjects, from both old and new buildings. The AC was turned off, for the previously mentioned reasons (Results with the AC turned on will be outlined in section7.3). Figure 7.4 shows the comparison of AMV between 9 old buildings and 10 new buildings. It shows that 54% of respondents, regarding the courtyard in the old buildings, reported their neutrality compared to only 22% regarding the equivalent sitting room in the new buildings. It also shows that 8% reported as being hot in the courtyard compared with 33% in the sitting room. Also, 8% of people felt warm in the courtyard while 26% felt warm in the sitting room.

Figure 7.5 shows the same trend as that in Figure 7.4, when the occupants reported their AMV related to the general building as a whole, but in 19 buildings (9 old, 10 new). It illustrates that 54% of the respondents are feeling neutral (0) in the old buildings and only 15% of the respondents in new buildings are feeling neutral. In addition, 13% of people reported as being slightly cool (-1) in the old buildings compared with 0% in the new buildings, with 8% of them feeling hot (3) in the old buildings, and 33% feeling hot in new buildings.

Furthermore, the survey showed, from the preference scale, that 62% of the residents in old buildings did not want a change in their indoor environment, while 38% wanted to be cooler. By comparison, only 41% of new building occupants voted for no change with 59% who wanted to be cooler. At the same time there were 96% who were generally satisfied with their environment of the old buildings, compared with 77% of occupants of the new buildings that were satisfied.

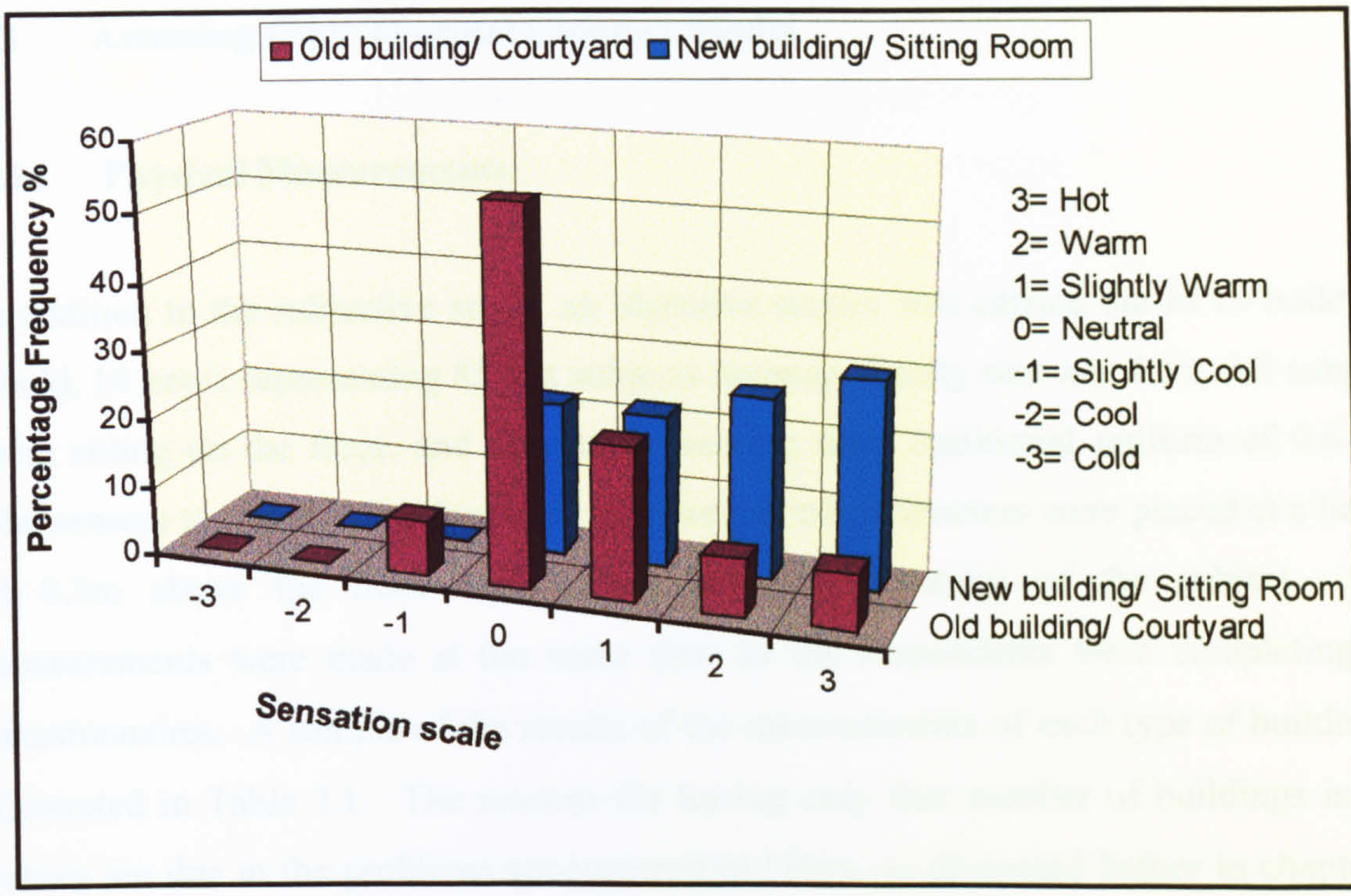


Figure 7.4: Comparison of the AMV for the courtyard in old buildings and for the sitting room in new buildings when AC was turned off.

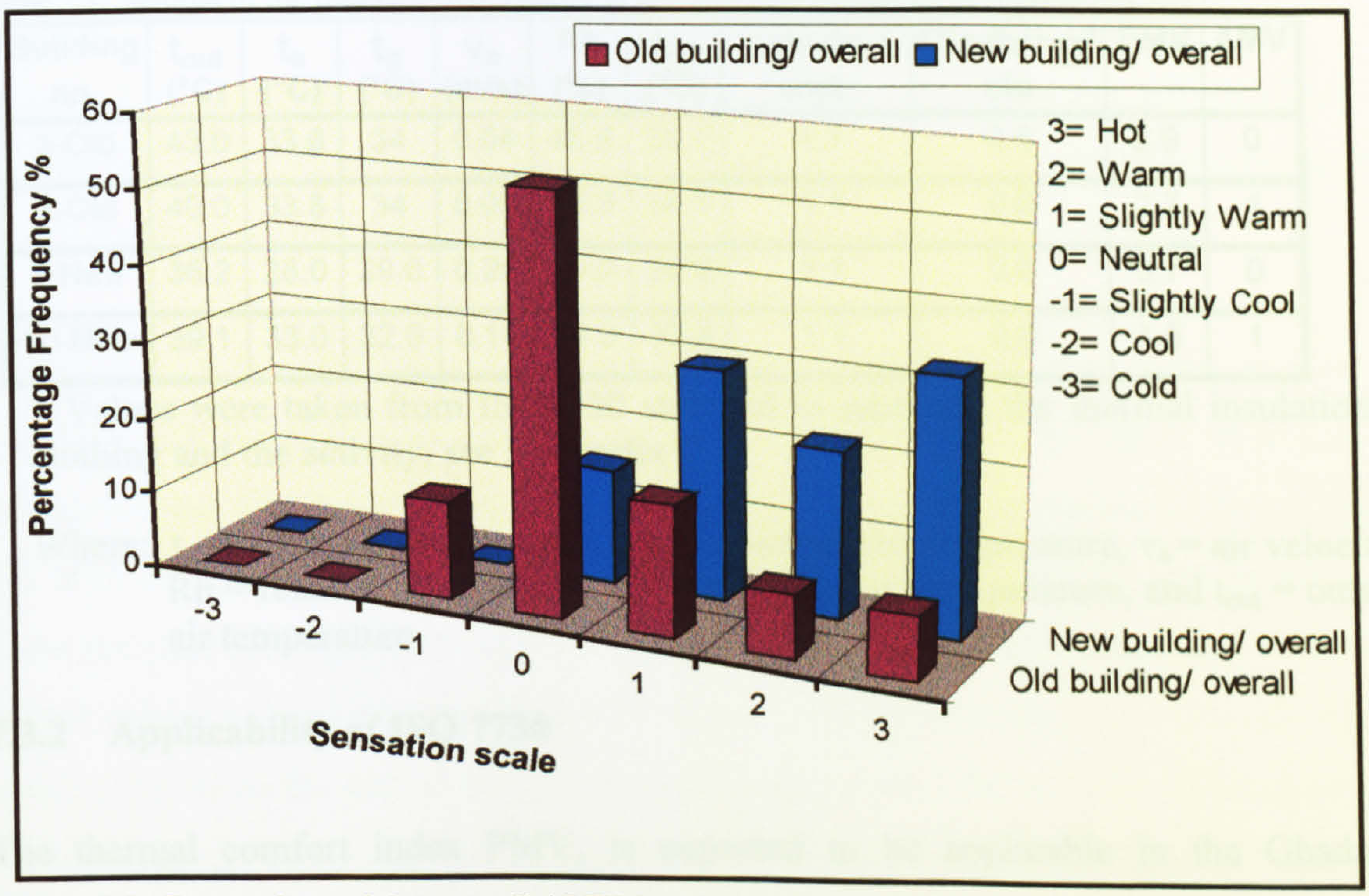


Figure7.5: Comparison of the overall AMV for old and new buildings, when AC was turned off.

7.3 Assessing PMV Thermal Comfort Model

7.3.1 Physical Measurements

In addition to the subjective study, an objective survey was carried out in 19 buildings (9 old, 10 new), representing 85 test subjects (average family size was 4.5). All subjects were sitting on the floor, and they were wearing their traditional uniform of 0.6 clo. The sensors to measure the four basic environmental parameters were placed at a height of 0.3m above the floor representing the centre gravity of the subject. The measurements were made at the same time as the respondents were completing the questionnaires. A sample of the results of the measurements of each type of building is illustrated in Table 7.1. The reasons for having only that number of buildings in this survey are due to the problems encountered in Libya, as discussed before in chapters 4 and 6.

Table 7.1: Sample of the measurement results of old and new buildings in Ghadames, 1997.

Building no.	t_{out} (°C)	t_a (°C)	t_g (°C)	v_a (m/s)	Rh (%)	t_{mr} (°C)	Activity* met.	Clothing* clo	PMV	AMV
3-Old	43.0	33.6	34	0.04	45.9	34.1	1.1	0.6	2.9	0
5-Old	40.0	33.8	34	0.05	35.3	34.1	1.1	0.6	2.7	1
7-New	36.2	28.0	29.0	0.20	20.0	30.0	1.1	0.6	0.7	0
10-New	39.1	33.0	32.0	0.19	29.0	33.6	1.1	0.6	1.8	1

* Values were taken from ISO7730 standard to represent the thermal insulation of clothing and the activity, see Appendix C.

Where: t_a = inside air temperature, t_g = inside globe temperature, v_a = air velocity, Rh = relative humidity, t_{mr} = mean radiant temperature, and t_{out} = outside air temperature.

7.3.2 Applicability of ISO 7730

The thermal comfort index PMV, is expected to be applicable in the Ghadames environment, for the following main reasons; a) Fanger's work investigated about 1296 subjects, with a wide range of environmental conditions, including conditions when air temperature > 30°C, and relative humidity 70%; b) A moderate thermal environment is achieved when PMV values range from –3 as cold to +3 as hot; and c) the people in

Ghadames are behaviourally and physiologically acclimatised to the heat. Therefore, the Ghadames environment is considered to be a moderate thermal environment and the ISO7730 standard is expected to be applicable in such environment.

A total of 85 test subjects in good health (residents from 9 old and from 10 new buildings), in the age range 20-50 years, were asked to complete the questionnaire to determine the actual mean vote (AMV). In the objective tests, measurements of environmental variables were used to calculate the predicted mean vote (PMV) of the subjects using Fanger's model as presented in ISO 7730 (1995). The thermal comfort programme developed by Loveday et al (1998) has been used to calculate PMV values. The measurements in the new buildings were conducted with the air-conditioning system operating, whilst the old buildings depended on natural ventilation. The metabolic rate was viewed to be 1.1 met (63.8 W/m^2) to represent a sedentary activity, and clothing value, Rcl, was estimated to be 0.85 m^2K/W or 0.6 clo representing the thermal resistance of a traditional uniform.

Figures 7.6 and 7.7 show the comparison of PMV and AMV for both old buildings and for new buildings. Each histogram bar in Figures 7.6 and 7.7 represents an average vote of 4.5 and 4.8 subjects respectively.

Figure 7.6 shows that two of the subjects were feeling slightly warm in two old buildings (no. 4 and 5) even when the indoor air-temperature was 30°C. It is possibly due to the fact that in this case, the occupants had adapted themselves to living part of the time in new buildings, which have air-conditioning systems. It can be seen that there are clear discrepancies between PMV and AMV for the old buildings, where 60% of test subjects voted neutral (0) on the thermal sensation scale, and 40% felt slightly warm (+1); when the indoor air-temperature ranged from 30°C to 35°C. This shows that Fanger's model is invalid for predicting the thermal comfort in such environments. Adaptation effects could explain this.

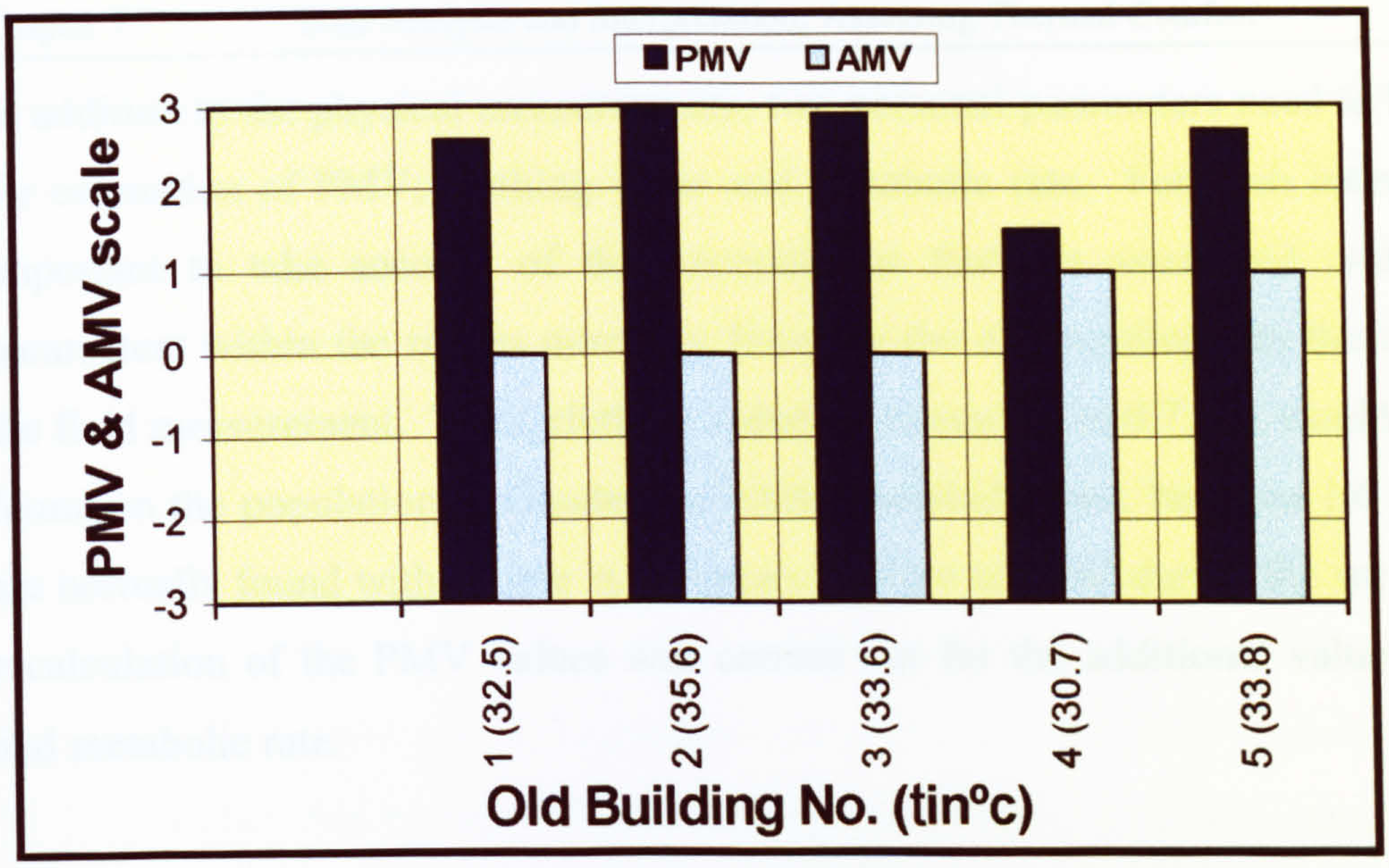


Figure 7.6: Comparison of PMV and AMV at 18:45 PM in five old buildings, 1997.

Figure 7.7 shows good agreements between the PMV values and the actual mean votes (AMV) of the occupants in new air-conditioned buildings when AC turned on. It shows that 67% of subjects in four new buildings were feeling neutral, while 33% were feeling slightly warm. The occupants in the newly constructed buildings had adapted themselves to rely more on the air-conditioning being turned on to achieve the thermal indoor air-temperature to be between 25°C and 31°C.

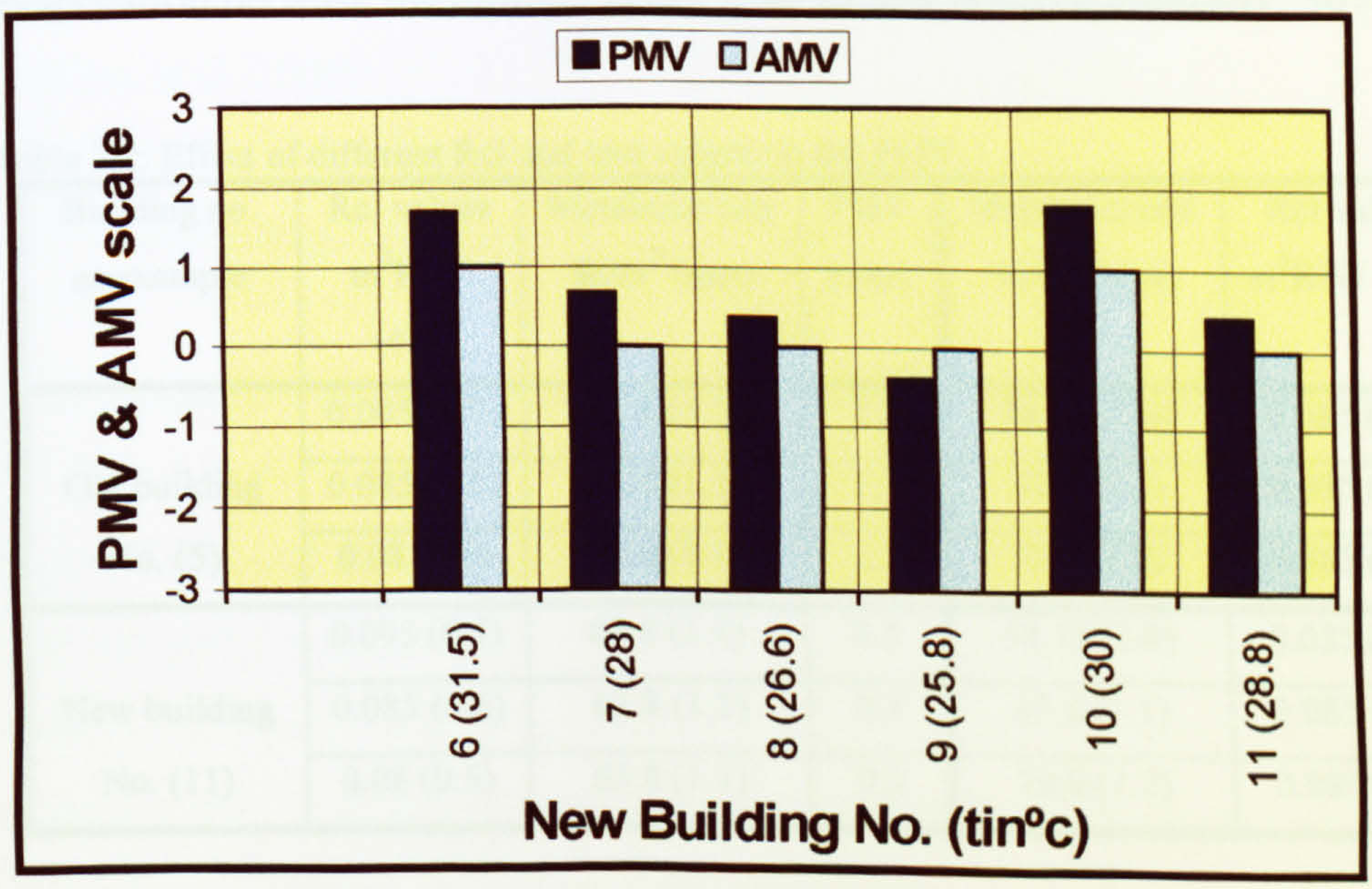


Figure 7.7: Comparison of PMV and AMV at18: 45 PM in six new buildings, 1997 (Air-conditioning systems turned on).

In addition to the physical measurements, two personal parameters need to be measured for estimation of PMV; clothing value and metabolic rate. For such estimations, it is important to take account of the uncertainties that are associated with these two parameters within the ranges normally found in the old buildings, in the conditions of the field measurement. Thus, clothing values between 0.5 to 0.7 clo, would normally be found on the population in Ghadames, whilst metabolic rate, between 1.0 and 1.2 met, are normally found with people in sedentary posture adapted during the survey. Thus, a recalculation of the PMV values was carried out for the additional values of clothing and metabolic rate.

These new values of PMV, as shown in Table 7.2, suggested that those different Rcl values when metabolic rate is constant 1.1 met, and metabolic rates when Rcl value is constant (0.6), had no significant effect in old buildings, in such environments. It is concluded that the existing standard ISO 7730 still shows disagreement with AMV values reported by the occupants in old buildings. Whilst, the ISO7730 standard still shows good agreement with AMV values reported by the occupants in new air-conditioned buildings. Thermal resistance or Rcl is not important when the temperature differences between the body surface and air is small, and heat loss is mainly by evaporation because the climate is dry (due to low relative humidity, 30%).

Table 7.2: Effect of different Rcl and met values on the PMV.

Building no. as example	Rcl values m^2K/W (clo)	Metabolic rate W/m^2 (met)	PMV value	Metabolic rate W/m^2 (met)	Rcl values m^2K/W (clo)	PMV value
Old building No. (5)	0.095 (0.7)	63.8 (1.1)	2.7	58.15 (1.0)	0.085 (0.6)	2.8
	0.085 (0.6)	63.8 (1.1)	2.7	63.8 (1.1)	0.085 (0.6)	2.7
	0.08 (0.5)	63.8 (1.1)	2.7	70.0 (1.2)	0.085 (0.6)	2.7
New building No. (11)	0.095 (0.7)	63.8 (1.1)	0.5	58.15 (1.0)	0.085 (0.6)	0.1
	0.085 (0.6)	63.8 (1.1)	0.4	63.8 (1.1)	0.085 (0.6)	0.4
	0.08 (0.5)	63.8 (1.1)	0.3	70.0 (1.2)	0.085 (0.6)	0.5

From additional general observations, two further initial comments may be made: - The first indication arises from environmental conditions in the buildings. The main climatic factor is air temperature as clearly shown in figures 7.4 and 7.5. Despite the difficult climatic conditions of Ghadames, the old buildings act as very effective climatic filters as a result of their long evolutionary development, therefore the majority of the occupants felt neutral. On the other hand the opposite condition has been observed in the new buildings.

The second indication can be highlighted from Humphreys (1976), when he concluded "it is probable that higher temperatures would become acceptable during prolonged warm spells, as people adapted their way of life to the prevailing thermal environment". This work is leading to form part of the research programme to investigate the validity of the "Adaptive model", referred to above.

The thermal environment can now be measured accurately in field studies. Although, a criticism of field studies is that they lack controlled or standard conditions (Humphreys 1995: 12) nevertheless the results are likely to form the foundation on which to base our future indoor air temperature standards, and emphasise the importance of investigating more real buildings. The initial discussion of these findings has already been presented (Ealiwa et al, 2000).

7.4 Assessing Adaptive Thermal Comfort Model

7.4.1 Adaptation Effects on New AC Buildings (on and off)

Figure 7.8 shows the relationship between the actual mean vote (AMV) of the subjects and the globe temperature in new buildings, as mentioned before at the beginning of section 7.2, when i) the air-conditioning system is turned on and ii) the air-conditioning system is off. It shows that subjects were neutral at globe temperature values between 25°C and 31°C, when the air conditioning system was in operation. Not surprisingly, on disabling the air conditioning system, the subjects expressed their thermal dissatisfaction when the globe temperatures exceeded values of 32°C. The people still felt *'neutral'* and *'slightly warm* (i.e. AMV = 0 & +1) even when the globe temperature reached 32°C. This became acceptable during prolonged warm spells, as people adapted their way of life to a new prevailing thermal environment.

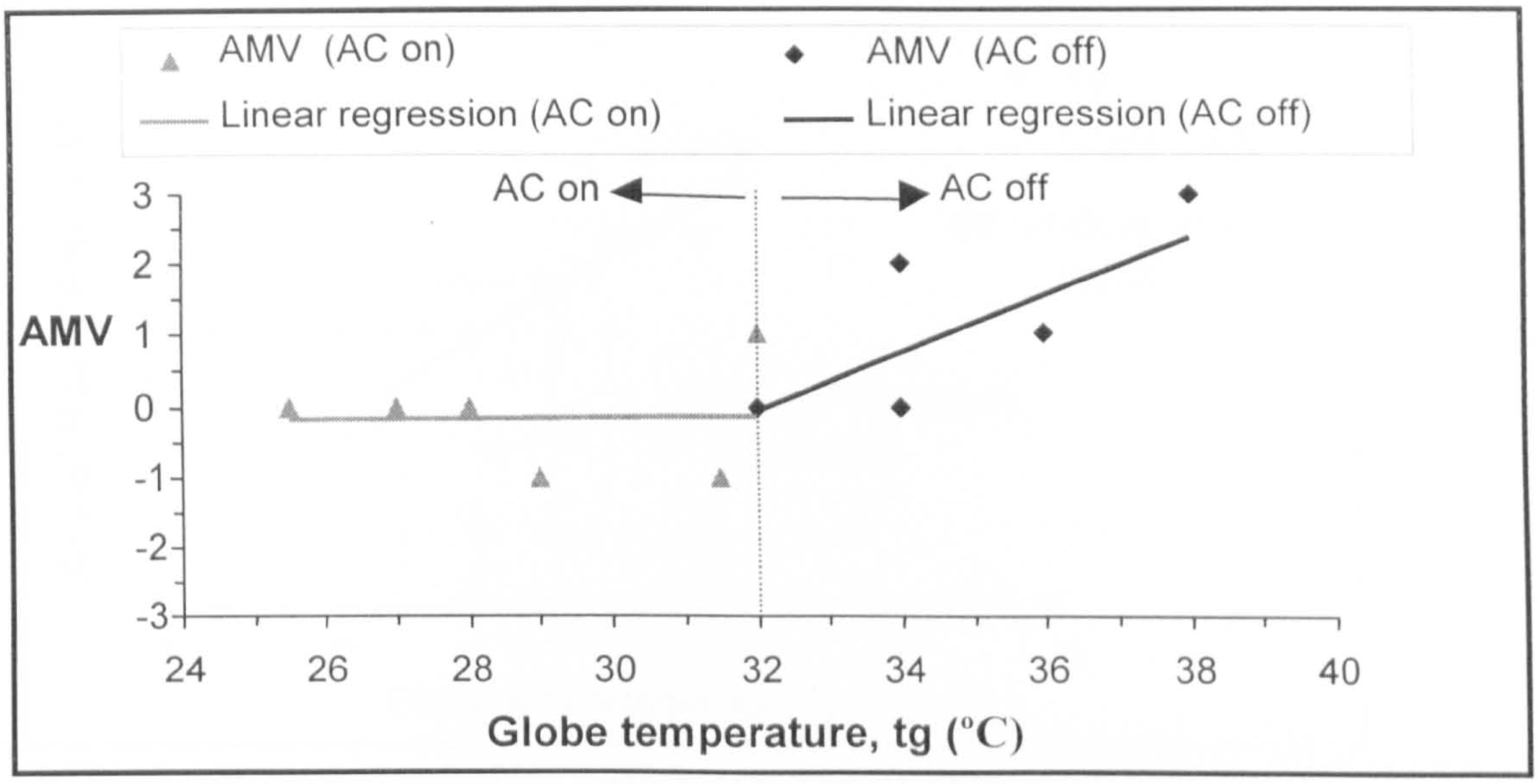


Figure 7.8: Responding of AMV of the residents in new buildings when air-conditioning turned off and on as a function of globe temperature in Ghadames, 1997-98.

7.4.2 Regression of Actual Mean Vote on Globe Temperature

From the questionnaires the actual mean votes (AMV) of the subjects were determined. The relationships between the AMV and globe temperature for both old and new buildings (when the AC was on) are shown in Figures 7.9 and 7.10 respectively. Lable buildings to be two types NV and AC buildings, did not interfere life style to control AC to be on or off as before. The results in Figure 7.10 show surprisingly that despite the fact that the globe temperature rose above the value of 32°C, which indicated as if AC was not in operation. This could be due to the intermittent use of the AC units where the occupants might turned the AC units on during the night until early morning in order to benefit from the pleasing natural outdoor breeze. Linear regression gives, for the old buildings (r = 0.88):

$$AMV = 0.6\ tg - 18.97 \qquad \longrightarrow (7.1)$$

and for the new buildings (r = 0.74):

$$AMV = 0.28\ tg - 8.23 \qquad \longrightarrow (7.2)$$

Figures 7.9 and 7.10 also show that the neutral temperatures of the subjects (i.e. when they feel neutral on their thermal sensation vote) are 31.6°C for old buildings and 29.4°C for new buildings.

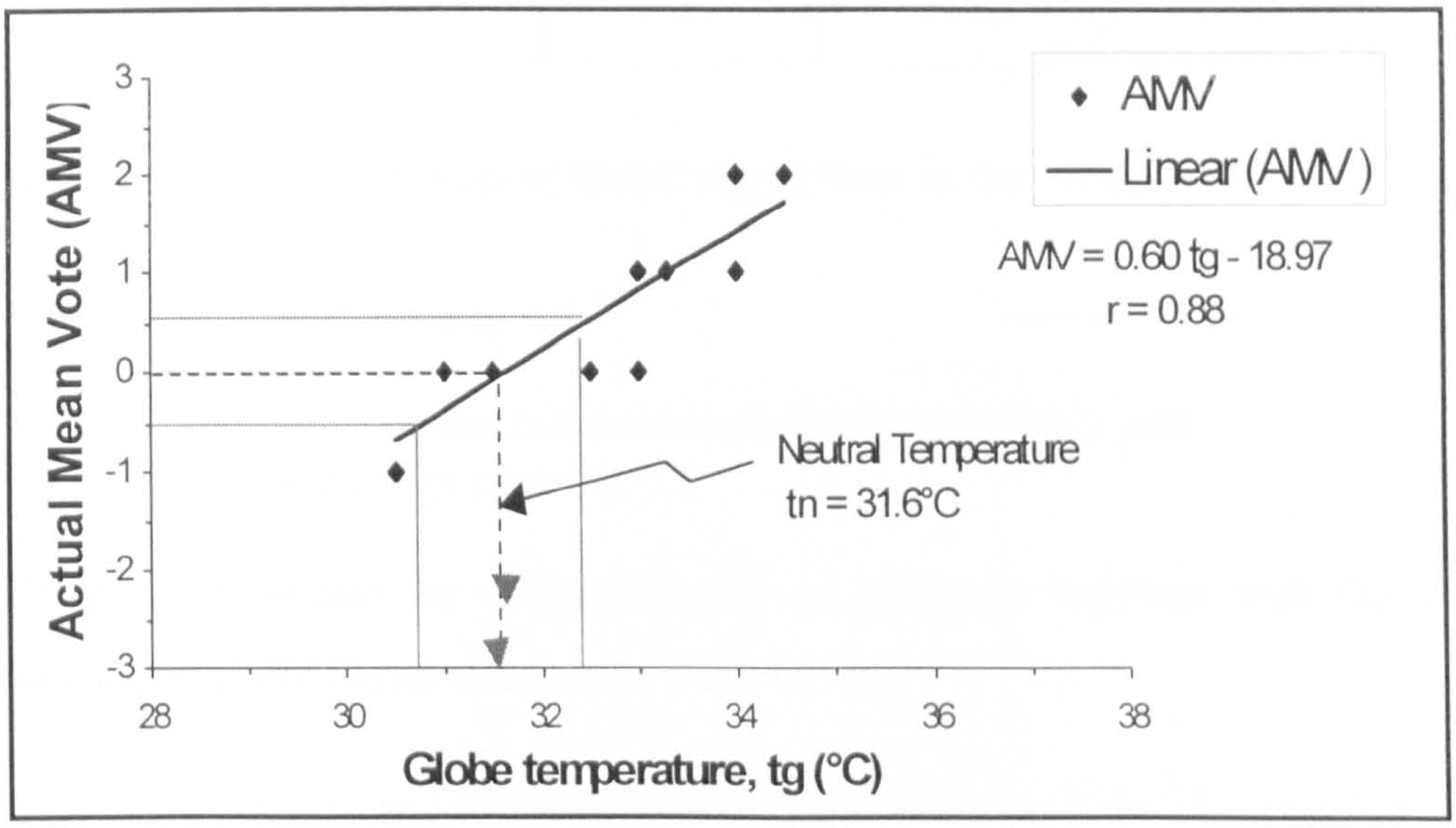


Figure 7.9: AMV versus globe temperature for old buildings in Ghadames.

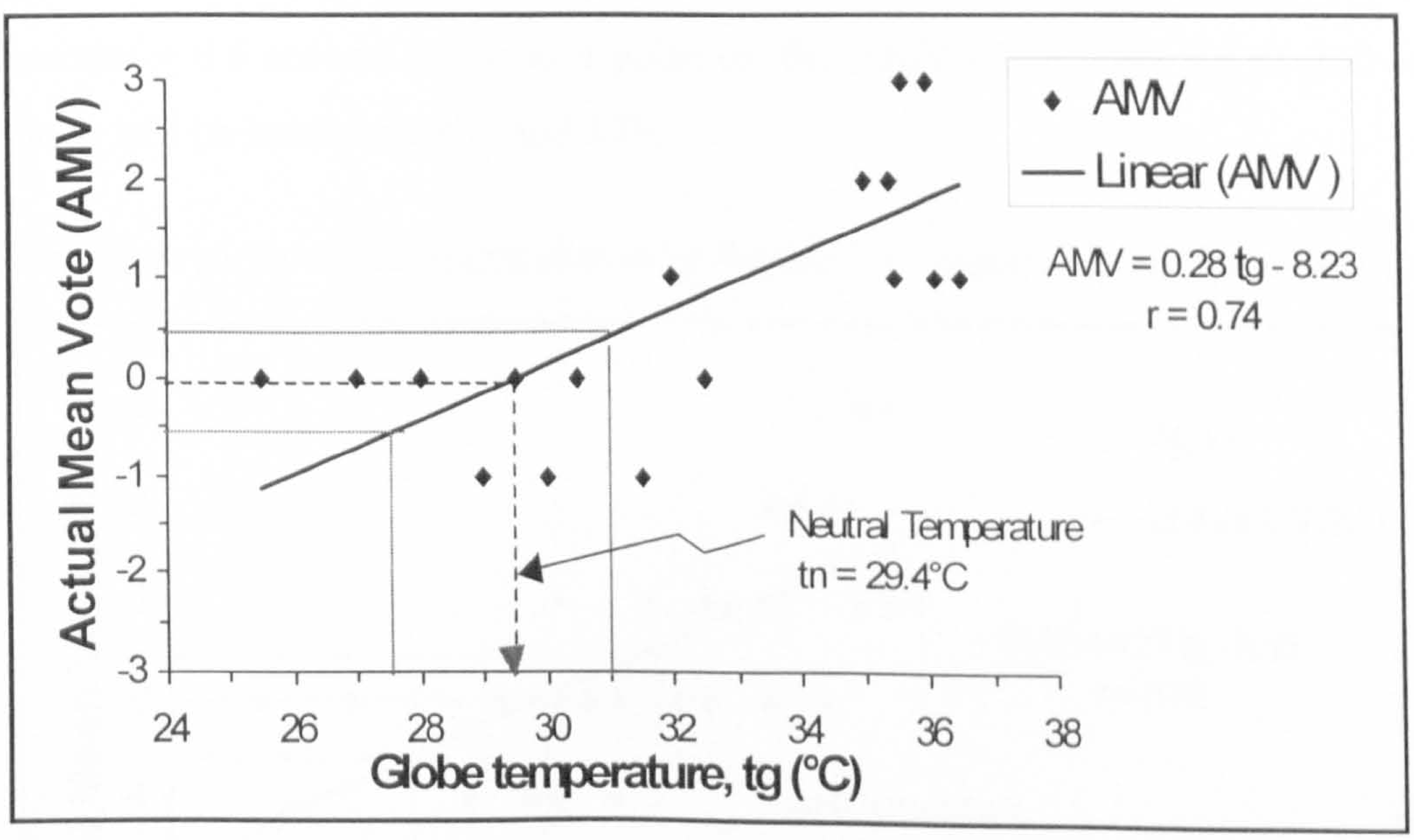


Figure 7.10: AMV versus globe temperature for new buildings in Ghadames.

The actual mean votes of all subjects for all (old and new) buildings are presented in Figure 7.11 giving (r = 0.67):

$$AMV = 0.27\ tg - 8.18 \qquad \longrightarrow (7.3)$$

Table 7.3: Linear regressions of AMV on tg for different types of buildings in Ghadames.

Type of building	Number of data points	Values for a	Values for b	Correlation coefficient r	Standard deviation
Old	12	0.60	-18.97	0.88	0.90
New	18	0.28	-8.23	0.74	1.35
All	30	0.27	-8.18	0.67	1.11

Table 7.3 shows the results of linear regressions in the form:

$$AMV = a\ tg + b \longrightarrow (7.4)$$

Where; a and b are constants determined from regressions, and
tg is globe temperature in °C.

These are presented for different types of buildings together with the corresponding correlation coefficients and standard deviations.

Figure 7.11 shows also that the neutral temperature in all types of buildings in Ghadames, whether free running or with climatic control, is about 30.3°C. Taking into account ± 0.5 around the neutral point on the AMV scale, then the neutral temperature range will be between 28°C and 32°C.

(Note that some of the points shown in Figure 7.11 represent duplicate data).

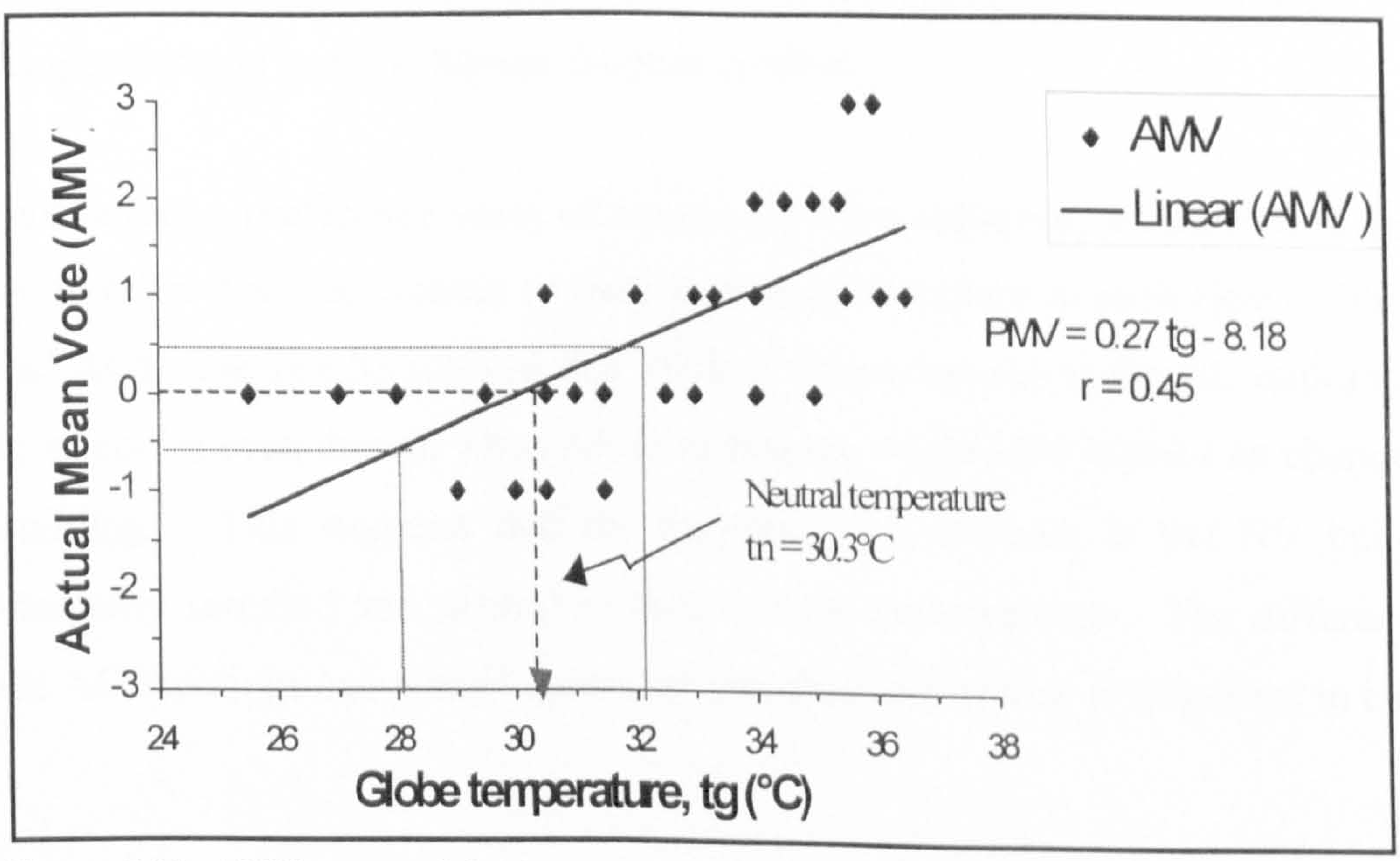


Figure 7.11: AMV versus globe temperature for all building tested in Ghadames.

7.4.3 Neutral temperature

Neutral temperature is defined to be the globe temperature at which subjects feel neutral based on their thermal sensation vote. When, for example, the AMV has a value of zero, tg from equation (7.4) becomes the neutral temperature and values of a and b can be found from Table 7.3. Thus, in the case of old buildings: -

$$t_n = (0 + 18.97) / 0.6 = 31.6°C \longrightarrow (7.5)$$

Following from this, Table 7.4 shows the neutral temperatures of all categories of buildings investigated.

Table 7.4: Neutral temperature in three categories of buildings in Ghadames

Type of Building	t_n (°C)
Old	31.6
New	29.4
All	30.3

It is clear that the occupants felt neutral at higher globe temperatures in these climates, as a result of their personal adaptation. However, it is not clear whether these temperatures are just considered as acceptable temperatures or simply the neutral temperatures to provide human thermal comfort.

Furthermore, preference votes of occupants were collected, as mentioned in chapter 6, to describe their preferences to their indoor environment in each type of buildings (NV and AC). The results showed that 70% of the occupants in the AC buildings preferred to be cooler even though when AC is turned on, while 60% wanted no change in the NV buildings. This suggests that the majority of occupants in the NV buildings were thermally satisfied and neutral in their indoor environments. The difference between the AC buildings occupants' neutrality and their preference is described in chapter 9.

7.4.4 Comparisons with other studies

Humphreys (1975) suggested in the adaptive hypothesis from about 35 field studies from Asia, Europe, and Australia, ranging from winter in Sweden to summer in Iraq, that the neutral temperature was related to the mean indoor air (t_{in}). The current analysis of data is based on the same approach, which means that the neutral temperature, t_n, is the globe temperature when the actual mean vote (AMV) has a value of zero. Humphreys has developed some linear regression to predict the neutral temperature, as described before in chapter 3, pages 52-53 (section 3.2.3.3).

As mentioned ealier in chapter 3 that Auliciems (1983) developed a linear regression of neutral temperature (t_n) as a function of inside mean air temperature (t_{in}), and outside mean air temperature (t_{out}). This has been taken as a statistical expression of the adaptive model of human thermal perception. The equation is:

$$t_n = 0.48\ t_{in} + 0.14\ t_{out} + 9.22 \quad (r = 0.97) \qquad \longrightarrow (7.6)$$

where t_n and t_{out} are in °C.

In addition to that, de Dear et al (1998) derived the following regression model in order to calculate the neutral temperature, for both NV and AC buildings:

$$t_n = 18.9 + 0.26\ t_{out} \quad (r = 0.97) \qquad \longrightarrow \text{(7.7) for NV buildings.}$$

$$t_n = 21.5 + 0.11\ t_{out} \quad (r = 0.97) \qquad \longrightarrow \text{(7.8) for AC buildings.}$$

Equations (7.6, 7.7 and 7.8) have been used to calculate the neutral temperature of the subjects, in the aim of comparison with the present study with works of Auliciems and de Dear. The weekly mean inside and outside air temperatures are presented in Table 7.5 (columns (2) and (3)) for different types of buildings in Ghadames oasis. Substituting the inside and the outside air temperatures for each type of building, as presented in columns (2) & (3) respectively in Table 7.5, using the adaptive model (equation (7.6)) and de Dear's equations (7.7 and 7.8), the neutral temperatures were calculated, and presented in columns 4 and 5. The neutral temperatures of the present study are shown in column 6. These values were derived from equation (7.4) and Tables 7.3 and 7.4.

It can be seen from Table 7.5 that there is very good agreement between the neutral temperatures predicted by the adaptive model (equation (7.6)) and those measured in the present study. However, it also shows that results of the present study do not agree with those predicted by de Dear's equations (7.7 and 7.8). Therefore, the adaptive model in the form of equation (7.6) is valid for predicting the thermal comfort of people in Ghadames, representing hot-dry climate environments. Thus the results of this work for the North African region are consistent with those of other researchers, who are working in a variety of climatic environments. The initial discussion of these results has been presented in Taki et al (1999).

Table 7.5: Comparisons of the neutral temperature from present study with de Dear et al (1998) and Auliciems (1983) equations.

Type of building (1)	t_{in} (°C) (2)	t_{out} (°C) (3)	t_n (°C) de Dear (1998) equations (7 & 8) (4)	t_n (°C) Auliciems (1983) equation (6). (5)	t_n (°C) present study (5)
Old	35.5	38.5	28.9	31.7	31.6
New	31.6	38.0	25.7	29.7	29.4
All	33.7	38.3	27.3	30.8	30.3

7.5 Conclusions

From full-scale analysis and evaluation of the results, the following conclusions can be drawn:

1. The general feeling of the occupants in Ghadames in the summer seasons, reported that their thermal sensation is more comfortable in 9 old naturally ventilated buildings than in 10 new air-conditioned buildings. In the old buildings, about 54% of the occupants felt neutral (0) and 8% felt hot (+3), compared to only 15% of the occupants felt neutral (0) and 33% felt hot (+3) in the new air-conditioned buildings.
2. The PMV model in the form of ISO 7730 (1995) cannot be used for such environments without modifications for predicting the overall thermal comfort of the occupants in old naturally ventilated buildings. These modifications would have to address issues related to adaptive effects. However, ISO7730 standard can be used to measure human thermal comfort in new air-conditioned buildings without modifications.

3. Comparing the behaviour of the residents in old and new buildings indicated that people in new buildings rely on their air-conditioning systems. The neutral temperatures were 31.6°C and 29.4°C for old and new buildings respectively. Building designs, together with acclimatisation effects, have significant implications on energy consumption for designing air conditioning systems, as the desired inside air temperature need not be less than 29°C. The majority of occupants (60%) in the traditional NV buildings were thermally satisfied and neutral, as they preferred no change to be made into their indoor environment.
4. The adaptive model as presented by Auliciems (1983) can be used without modification for predicting the overall thermal comfort of the occupants, in such environments. The neutral temperature in naturally ventilated buildings is higher than that in new AC buildings.
5. Such satisfaction of thermal comfort in this harsh climate at these high temperatures can be only achieved when it is based on acclimatisation effects and adaptation, together with past experiences. This confirms the effect of the outdoor climate on the perception of thermal comfort, which would be discussed in detail in chapter 9.

Chapter Eight:

THE EFFECT OF OUTDOOR CLIMATE AND ACCLIMATISATION ON HUMAN PERCEPTION OF THERMAL COMFORT

"World Bank, believe that respect for the culture and identity of peoples is an important constituent element in any viable approach to people – centred development."

(A letter statement by James D. Walfensohn, 1998, as a president of the World Bank).

8.1 Introduction

The climate in Ghadames is mainly "hot-dry" with very wide differences between day and night outside climate as described before in chapter 5. Simply because of almost complete absence of cloud screening, the ground by day receives large amounts of solar radiation, while at night it radiates a great amount of heat out to the sky again. The evaluation and analysis of the data has used the two widely used models of thermal comfort to assess their validity in such environments (i.e. PMV and Adaptive models). Then results have indicated that the PMV model could not work without modification. While the adaptive model could work without modification to assess the thermal comfort in the case of the traditional buildings, even though the investigations have been carried out in the same area and in the same climatic conditions for both types of buildings during summer season in Ghadames Oasis. The residents indicated, as mentioned in the previous chapter, that they felt comfortable, especially those living in the old buildings, because they have successfully acclimatised themselves with such climatic conditions. The thermal interaction between human and the environment is very open ended and highly complex. It has been the subject of many studies, which have addressed the internal processes of human feelings about the environment by which people's life style and respond to the climate, based on their social aspects and personal acclimatisation. Social issues determine how people react to the environment, which is the realm of the social sciences. It is the role of the environmental engineers to decide how the requirements of the residents can be satisfied within the buildings to provide a comfortable indoor environment. Thus, this chapter focuses on the relationship between the occupants of buildings and their thermal indoor environment including different forms of social aspects and personal acclimatisation. The main objectives of this chapter therefore are:

I. To address the main interactions between the human and the environment, including the human-body response with the outdoor climate, for thermal comfort studies.
II. To analyse the effects of the outdoor climate on the social aspects and personal acclimatisation.
III. To highlight the local knowledge and experiences of the traditional courtyard design form amongst people and builder.

8.2- The Incorporation of Social and Personal Acclimatisation into Adaptive Model

The adaptation approach is based on the fact that there is a range of actions that a human being can and does take in order to achieve thermal comfort. Adaptation to climatic differences may arise from different ways of life according to the region – i.e. religions, working patterns, diet etc. The implication of the adaptive principal is that given sufficient time, people will find ways in which to adapt to any temperature so long as it does not pose a threat of heat stroke or hypothermia. Nicol, (1993: 26) stated that

> "Comfort standards based on adaptive assumptions will be more than simply a temperature to aim at. The standard will need to reflect the interactions between comfort and environment in its formulation. Such concepts as predictability, constraint, variety, and control will need to be incorporated into standard".

Therefore there is a need for more research on thermal comfort globally, which will then enable researchers to gain more experience in achieving the desired thermal environment. The results in chapter 7 show clearly that the adaptive model can be used to predict the thermal comfort without modification in such environment (i.e. hot-dry climate).

This is due to the fact that the adaptive model involves other important factors that are needed to take into consideration, when researchers want to study the thermal comfort. The thermal adaptation can be attributed to the human conscious feeling about the outdoor environment, the processes of heat transfer between man and environment, and also personal and social acclimatisation. The later might play the most significant role in explaining the differences between observed and predicted thermal sensations and acceptability in the PMV model, as illustrated in Figure 8.1. This would be discussed in more details in chapter 10.

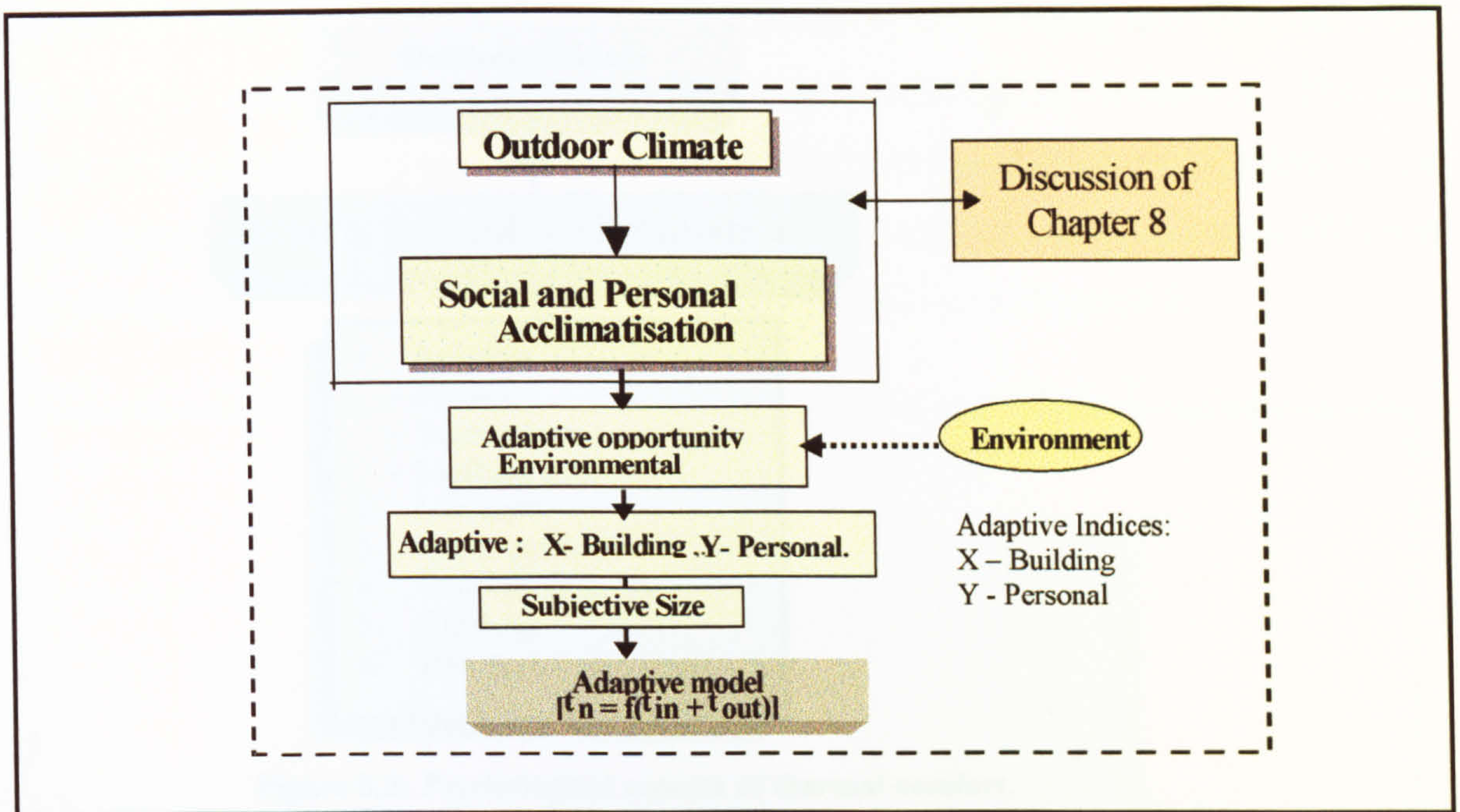


Figure 8.1: The hypothesis of the adaptive model of thermal comfort.
Developed from de Dear, (1994: p107) and Oseland (1994: p234).

Referring to Figure 8.1, the outdoor climate has an implication on the social and personal acclimatisation factors, which are being analysed in this chapter. In fact, these factors have strong relationships with both the behaviour of the occupants and their past experiences in each region where generations used to inherit their experience, on the way to deal with the climate in that region and design their buildings, to the following generation. Figure 8.2 illustrates the social and personal acclimatisation in terms of religion, diet, clothing, exposure, people's behaviour, socio-cultural incentive and activity. In order to understand these issues, there was a section of the questionnaire that was designed to investigate the general aspect of life and future well being, as described before in chapter 6 (Procedure, 6.2.1). People in the hot-dry regions construct their buildings in such a way that they can enhance the indoor environment by preventing the penetration of direct solar radiation from outside. This can be achieved by having, for example, a thick wall (i.e. heat storage), small windows, shaded and narrow streets, natural ventilation (i.e. pleasing night breeze), etc. This contrasts with conditions in Northern Europe where the cool climate results in a need to warm their indoor areas. In terms of controlling their openings, therefore, in Ghadames regions for instance, the people design their buildings to control the indoor environment in a way to try to benefit from the night cool breeze through the courtyard and the open shaded public squares.

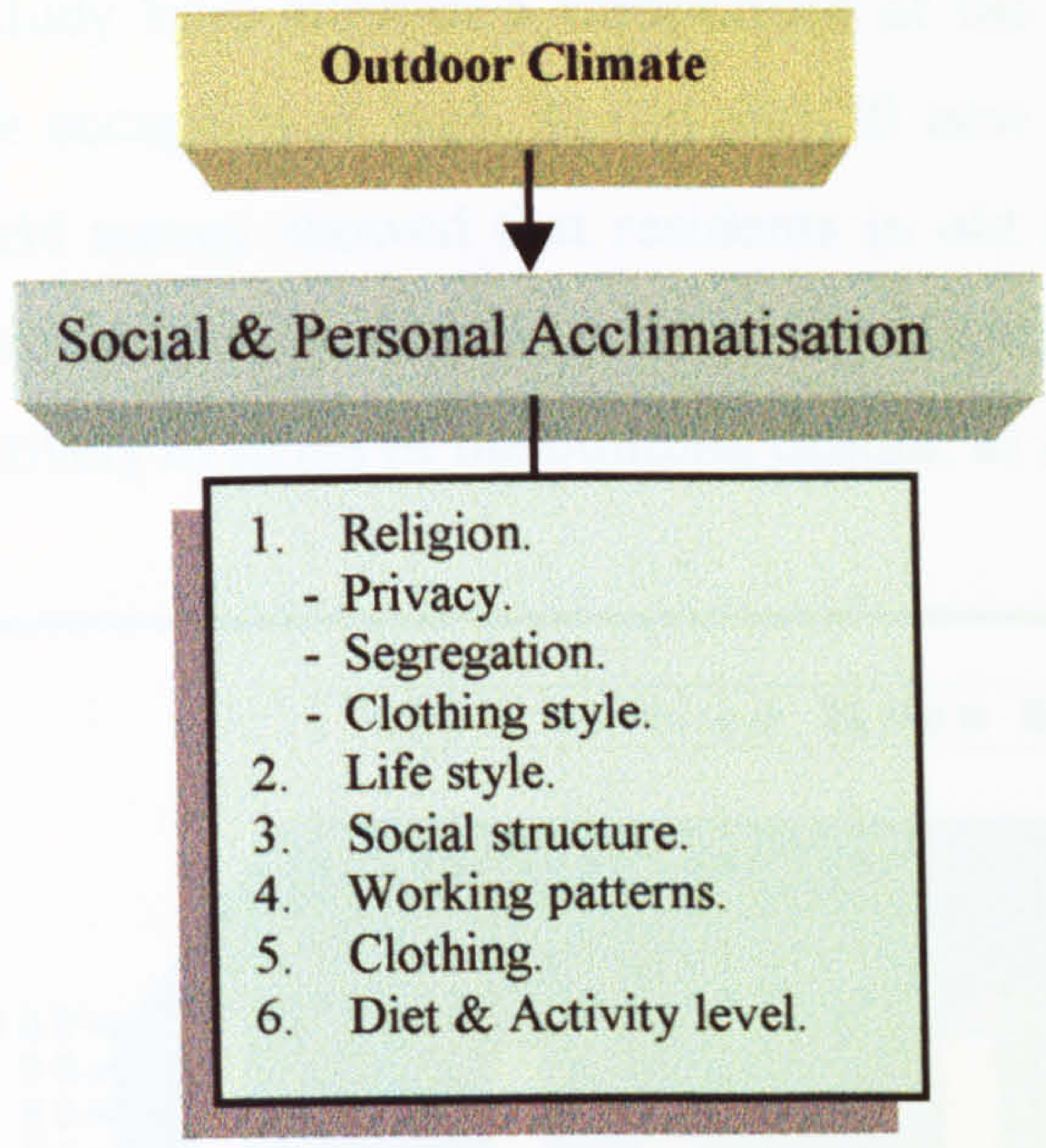


Figure 8.2: Psychological aspects of thermal comfort.

On the other hand, they are aware about the extreme and severe outside climate they are living with; therefore they use natural construction materials, which have high insulation ability and high thermal mass. The insulation is provided by mud, 50cm thick, plastered with lime and supported by palm tree trunks, then covered with 'fronds' and mud mixed with gypsum. Furthermore, their traditional design form is aesthetically pleasing, blending well with the environment. The dwellings are built two storeys high with a central room on the first floor, i.e. a courtyard, which functions as provider of cool ventilation with all other rooms around it (see chapter 2, Figures 2.7 and 2.8). The rooms are lit via the top hole in the high ceiling, which lets in sunlight that reflects off the white walls, providing sufficient illumination. In Ghadames, Design strategies the people followed to maintain their living environment of both indoor and outdoor spaces in their buildings within a very comfortable indoor environment naturally without using any mechanical and electrical equipment. A high courtyard, which is located in the centre of each traditional building, is a feature of the design providing shade in the early morning and late evening. While during the day, as the air heats up in the courtyard, it rises and draws hot air out of the adjacent rooms. Openings on the outside are minimal to avoid glare, dust and solar heat gain. Airflow is controllable using adjustable openings; such as the small opening in the roof of the courtyard, windows and doors, etc. These ventilation inlets are normally opened after 5PM till 11AM the next day to benefit from the night cooling breeze in the summer seasons. The results of the subjective study have allowed a comparison of the general feeling and personal well-being of the occupants at both 30 old and 30 new buildings in Ghadames. The data from the field survey showed that residents in old and new buildings indicated in the questionnaire that they would like to have courtyards in future building design, 96% and 89% respectively in terms of the building design, as shown in Figure 8.3.

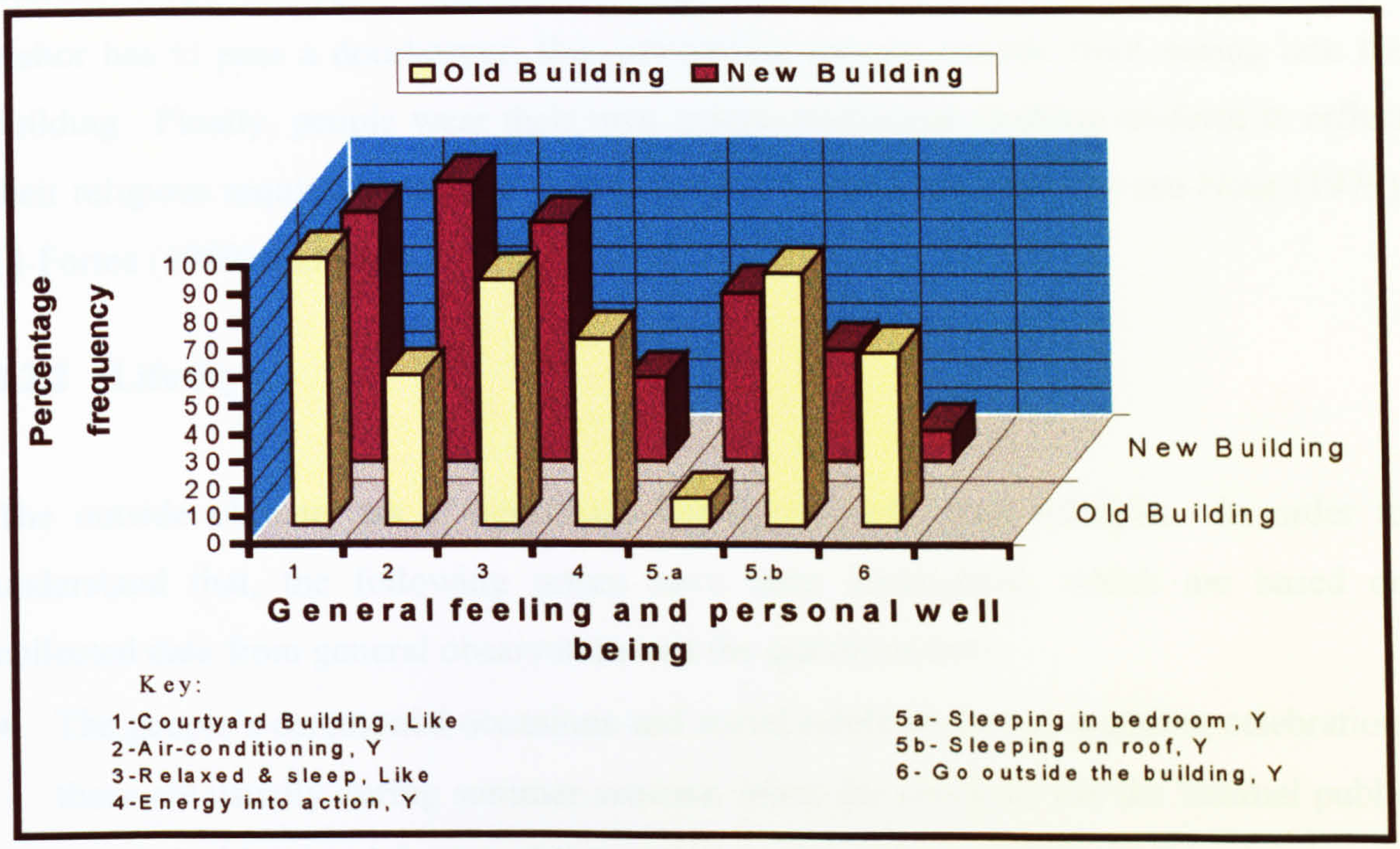


Figure 8.3: Comparison of the general feeling between old and new building.

Human behaviour is very important, because it combines socio-cultural issues and past experiences of any society. It plays an important role in human thermal interaction with the environment. The following points, which have been collected from the field survey through the questionnaires and the observation, describe the importance of behavioural aspects on thermal comfort in Ghadames.

8.2.1 Religion

Due to the socio-cultural way of life and the religion of the people (Islam), the old buildings have been planned and designed to fulfil their requirements more than the new buildings. These requirements were identified as a result of both interviewing the people of Ghadames and general observations:- Firstly, in terms of security and privacy, from public (street) to semi-public to private (house). The traditional architecture incorporates features for security and privacy levels, which are appropriate for both religious and cultural purposes. Secondly, segregation and privacy between sexes is one of the most essential characteristics of Islamic society, and these considerations can clearly be seen in the design of the traditional buildings in Libya generally and in Ghadames specifically. Thus, the building is designed in such a way that on entry a visitor has to pass a doorkeeper, thus preventing anyone outside from seeing into the building. Finally, people wear their own unique traditional clothing uniform to reflect their religious requirements. For further details, it is recommended to see Nour (1979), El-Fortea (1989) and Ealiwa (1996).

8.2.2 Life Style

The outside climate has a significant impact on individual lifestyle. In order to understand that, the following issues have been highlighted, which are based on collected data from general observation and the questionnaires:

- The people's ceremonial occasions and social celebrations e.g. wedding celebration: these are usually during summer seasons, when the residents use the internal public squares without causing any interruption to the daily activities of the other people who are living in other zones of the town, as shown in Figure 8.4. By comparison, in the new town of Ghadames, where there are no public places, these kind of cultural aspect however have been ignored and not considered in the planning stage of the new town by foreign planners. The people consequently closed some public streets by using the external spaces (i.e. road pavement) causing problems of traffic flow, as shown in Figure 8.5.
- Acclimatisation: this includes the changes in different places (i.e. courtyard, roof or bedroom) due to the physiological thermo-regulation system over a period of days or weeks, in response to the climate. The acclimatisation of the human being over a period of days or weeks and seasons could be seen clearly in the case of Ghadames. Figure 8.3 shows also that 90% of residents in the traditional buildings have adapted themselves to sleep on the roofs (taking advantage of night cool breeze), comparing with 30% of that in the new buildings. In fact, 70% of residents in the new buildings use their bedrooms relying on the use of air-conditioning system.

Figure 8.4: Old Town
This old architecture highlights the usage of the shaded pedestrianised of interior road system (Public Square) together with thick walls, during one of the ceremonial occasion without interrupting the daily activities. It is clear that this type of planning has taken into consideration the socio-cultural habits.

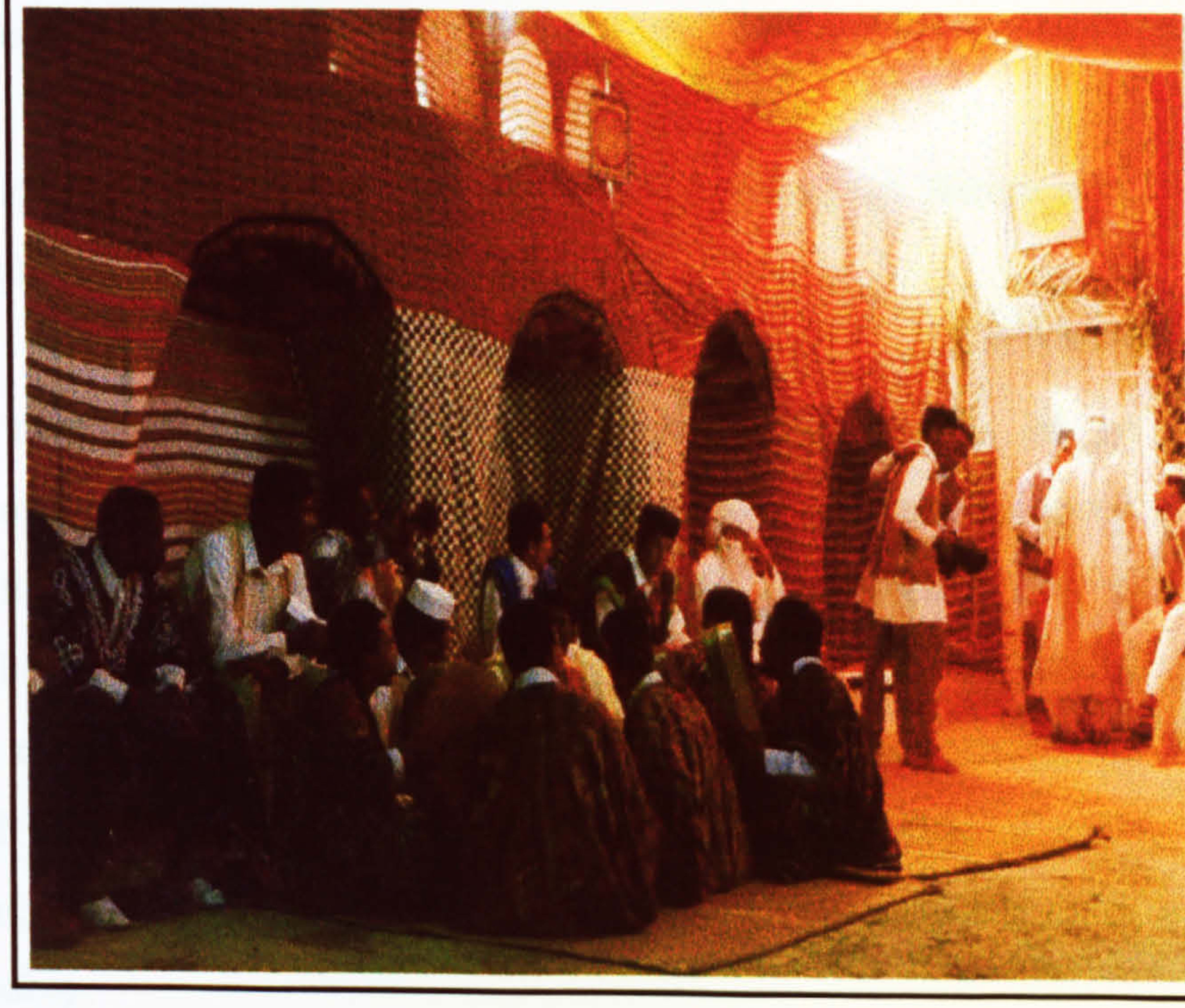


Fig.:- 8.5: New Town
This new development highlights the usage of the external space (road pavement), during one of the ceremonial occasion (wedding celebration). Scale of planning un-fortunately, did not take into consideration these kind of socio-cultural habits or benefit from the old design and planning features, when constructed the new town. This cause problems of daily traffic flow.

8.2.3 Socio-cultural Incentive

This deals with social actions of residents as well as their exposure on design and upholding traditions, through the following points:

- As mentioned before the traditional architecture in Ghadames consists of an elaborate composition of a variety of space ranging from extremely well sheltered rooms on the ground floor to the completely exposed roof. This architecture is unique in that it combines compactness with minimum exposure to the sun to provide privacy for the residents, as shown in Figures 8.6 and 8.7. These buildings are also closer to each other on three sides as terraces, and the façade of each building faces the street, which is covered to provide shadow for the people to sit or meet and walk comfortably.

- Figures 8.6 and 8.7 show that the planning of the vernacular settlement of Ghadames has co-operated with the natural surrounding features in the design of dwelling units. This has provided township complex in harmony with nature. The white colour plaster reflects the solar radiation away from all surfaces of buildings that are facing directly the sunrays. The foliage from the date palm trees (main food resource) filters the dusty hot air and cools it down before it reaches the courtyards or the roofs of the buildings. The shaded and narrow entrances into the complex provide shade as well as security to the residents.

- Residents find it more comfortable for themselves in their harsh climate to acclimatise themselves by dividing their daily activities into two parts. For instance, they live downstairs during the day, protected by the thick structural walls of each building and the roof, together with shaded narrow streets, which end with public squares in each zone of the old town with enough shadow and light. At night they move up onto the roof to sleep in the cool night breeze. However, the date palm-trees, which are surrounding the old town, help to modify it more and work as a filter. The principle is to shelter behind very thick mud wall by day, and to sleep on the roof under a tent or something equally thin at night. There would in fact be a need for a light structure over the upstairs areas to keep as much solar radiation, which is gained from the sun during the daytime, as possible off the downstairs. The old men are usually seated in the alley-ways where they spend most of their time, especially during the daytime.

Figure 8.6: Old town

Surrounding the complex are date palm trees which provide protection from the prevailing winds that carries the dust from the desert. The buildings usually are built up only to three storeys level. The foliage of the palm trees also provide shade to the dwellings. Together, these provide a very pleasing atmosphere to the whole setting.

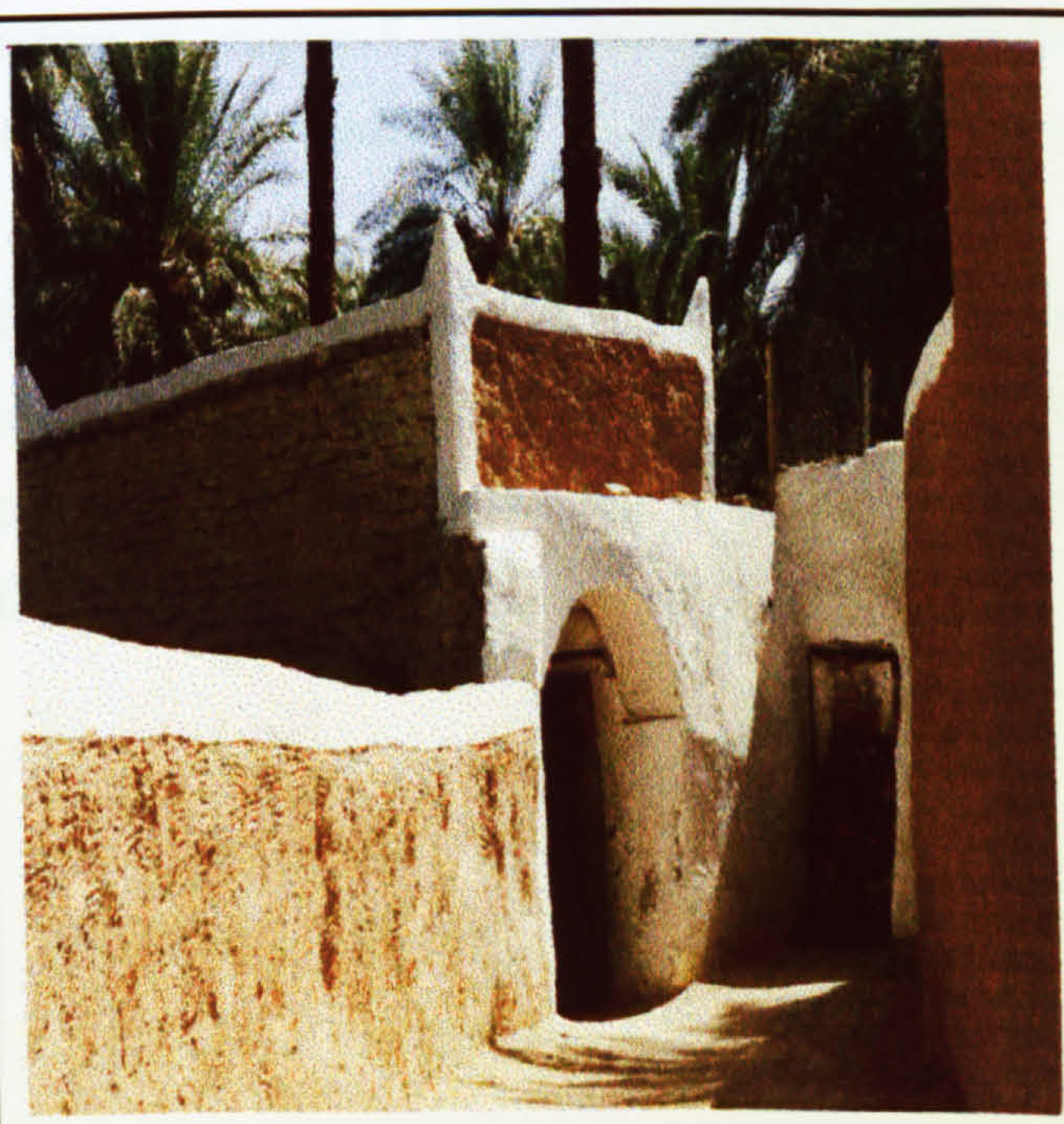


Figure 8.7: Old town

This narrow street leads to an archway that leads into the communal living spaces of the families inside. The entrance of the archway is painted white which gave a bright and well coming entrance to the buildings. This shaded narrow archway controls the entrance into the living units providing security to the families. This shadow and air movement controlling minimising the solar radiation, which means that the people are aware of the outdoor climate.

- Yet thick mud brick walls are not a perfect means of keeping cool, for although mud is a poor heat conductor, it retains heat for a long time. Thus the wall that keeps the residents cool inside their buildings or within the streets of their town all morning has actually been taking in and storing up the heat that falls upon it. Nevertheless, it will radiate this heat out again all through the night, partly into the room. For this reason, during the summer, it is much hotter in summer nights within mud brick dwellings, especially in downstairs rooms on the first floor. As a consequence, people adapt themselves by moving to different parts of their buildings during the day.

Figure 8.8 shows the analysis of the data from the questionnaire that covered the socoi-cultural interaction represented 135 subjects within 30 old buildings, and another 135 subjects within also 30 new buildings. There were 92% of respondents from the old buildings who considered them-selves to be too close to their neighbours compared to 77% in the new buildings. There were also 71% of the respondents from the old buildings who definitely talk to their neighbours while only 44% of people in the new buildings talk to their neighbours. This is due to the fact that the residents in the old town are one tribe (Ghadamesian) which is divided into many families, as described before in chapter 5. Each family is allocated their own zone or district, which means that they know each other because they are relatives.

The new government policy that has been implemented moves the residents from the old town into the new town, where they are distributed randomly within the newly constructed buildings mixing with different tribes and other strangers who came to Ghadames for work.

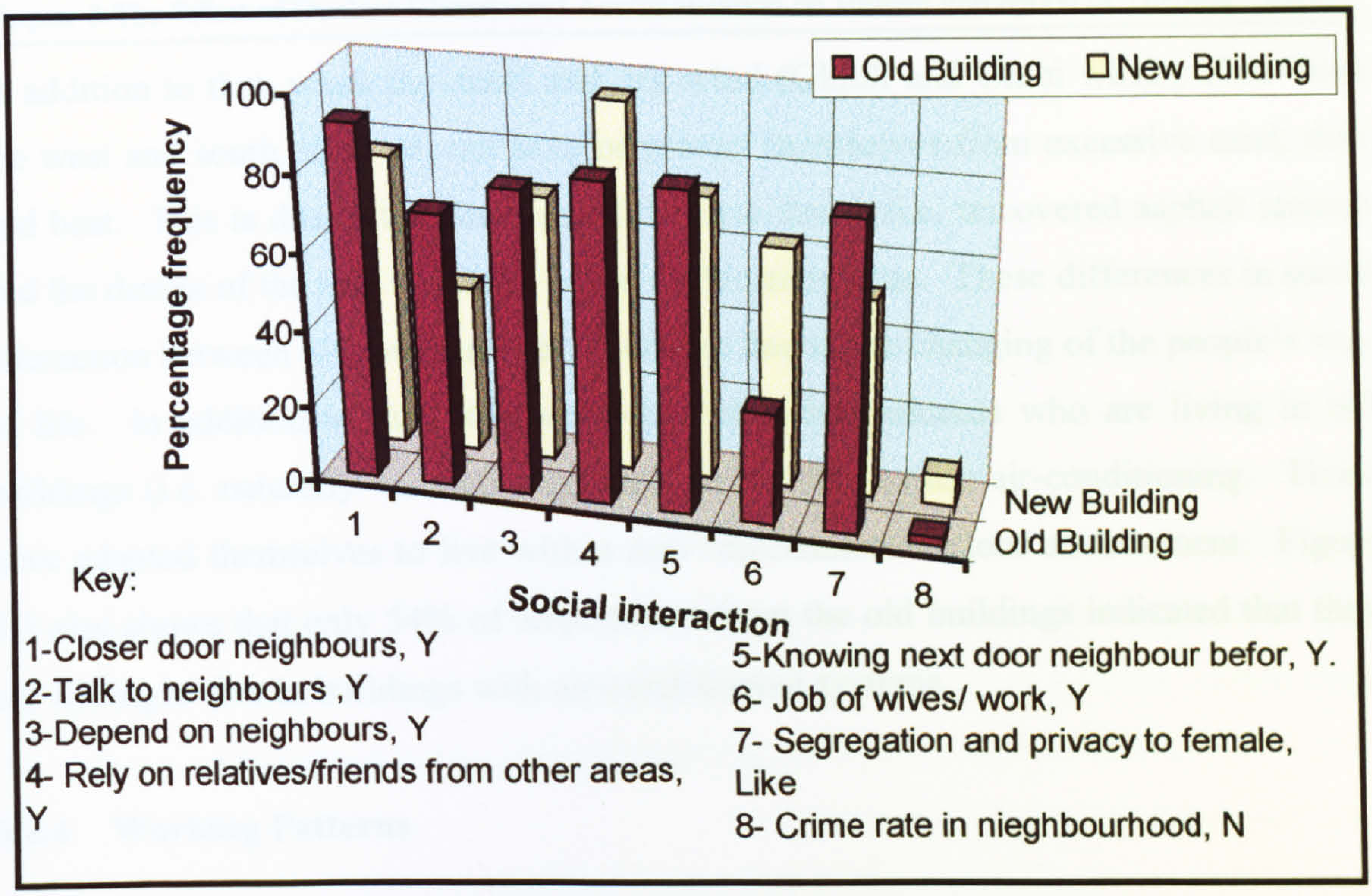


Figure 8.8: Comparison of the Social issues between old and new buildings.

Figure 8.8 also shows that 81% reported that they liked the segregation and privacy level that has been provided for their females from old town compared to only 50% in new town. However, the crime rates within neighbourhoods were still very low (2% in old town and 8% in new town). In addition, the collected data from the interviews and the observations of the Author indicated that more people in the new town did not know each other, which has a considerable effect on the family's relationships within each new district. For example, it was found at the second bar in Figure 8.8 that 66% of respondents from the old buildings knew more than 15 relatives in their neighbourhood compared with only 30% of respondents in new buildings. There was also a change in wives' role so that only 29% of wives were working in the old town compared to that of 63% in the new town.

It has been indicated from the Author's observations that in the new town, the people cannot go out of their buildings during the time between 12:00 noon until 18:00 evening, and during this period of time it is very important for the air-conditioning to be turned on. These tow facts happened as actions or responses from the residents in Ghadames region simply because the outdoor climate at that period was extremely hot.

In addition to that, when the dusty and dry wind (Ghibli and Garbi winds) blow from the west and south, they can not save or protect themselves from excessive sand, dust and heat. This is due to the planning of the new towns (i.e. uncovered asphalt streets) and the design of the new buildings based on Western ideas. These differences in social interaction between old town and new town are due to the changing of the people's way of life. In addition to that, it is very clear that the residents who are living in old buildings (i.e. naturally ventilated system), do not like to use air-conditioning. Those have adapted themselves to live with a new 'mechanical' indoor environment. Figure 8.3 also shows that only 54% of respondents from the old buildings indicated that they are willing to live in buildings with air-conditioning systems.

8.2.4 Working Patterns

In the case of hot-dry regions in Africa individuals have working patterns different from those in Europe. For instance, in Libya, individuals start their work very early in the morning (6-7 AM), due to the earlier day-light; also the breeze from the previous night makes it conducive for work. In the early afternoon (between 12-2 PM) people become less active because of loss of energy due to excessive heat, and all official government offices are closed. In Europe, people start their work usually from 9 AM until 5 PM, and their working patterns are not interrupted, due to the very cold climate very early in the morning.

In Ghadames, the individual sits in cool covered shades (alleyway) and is protected from the extreme heat, especially in the midday when the outside temperature can reach 46°C in summer. The residents express their social and cultural adaptation, in terms of relaxation and sleep in the mid-day (i.e. 2-6 PM) due to the extreme outdoor temperature in that region. It has been found almost the same response in both old and new buildings (86% and 85% respectively). Despite of that, there are big differences of life or actions of the residents in each type of buildings.

Figure 8.3 has also indicated that the people who are living in old buildings are more active and got more energy in to action (67%) during the hottest time of the day, compared with those who are living in new buildings (30%). At the same time, the residents in the old town still can go outside their buildings (62%, compared with that of 11% in new buildings) at that hottest time. The reason behind that is due to their traditional design of buildings and the whole town, which is divided into public squares where people meet each other under shaded places provided by buildings near to each other with narrow streets. They are also different in their behaviour even at their choice of sleeping places during the night. In old buildings only 10% of the residents are sleeping in bedrooms and 90% are sleeping in the roofs of their buildings, while in the new town, about 60% of the residents are sleeping in bedrooms, 40% in the roof. This is due to existing and usage of the air-conditioning systems in each room, which make the majority of the occupants in the new buildings rely more on them (AC).

8.2.5 Clothing

In some hot-dry climates, the residents wear loose, multiple layered clothing. The function of the clothing is then to keep the high environmental temperatures away from the skin, whilst allowing heat loss by evaporation when dry air is pumped through the clothing as the body moves. Sometimes people's clothing is determined by their social background as well as their thermal needs.

In such a large country as Libya, each region differs from others, in the way people have adapted to the climate. For instance, in the South of Libya (hot region) there are some tribes (i.e. Taureqs, Ghadamsies, Tebus and others) well known for successfully adapting themselves to the harsh climatic conditions of their environment by wearing special white clothes, covering their faces and heads except their eyes. They also plan their daily movement very carefully at the early morning and the late afternoon climates for summer activities. In the North regions (cool areas such as the mountain) people wear a 'Jared', which has multipurpose use, so it can be used as a blanket, or carpet, or as a curtain to divide a tent into two parts (see Figures 8.9.and 8.10). In hot-dry climate individuals tend to dress in light clothing during the summer season due to the extreme hot temperature they are facing and living with.

8.2.6 Diet and activity level

In hot-dry climates individuals have usually three main meals a day. The main heavy meal they eat in the afternoon (i.e. between 2-3 PM) followed by a siesta (for about two hours). After that the outside climate becomes bearable and people continue their normal daily activities. People adapt by eating just before siesta making habitation possible in very hot weather. The metabolic rate, which shows ability to generate heat, is mostly a function of the level of muscular activity. It is well known that the basic activities, according to the priorities placed upon them by the traditional society, can have a profound effect on the building form. These activities are physical actions, such as the parameter known as metabolic rate, like playing or exercise and working. This shows regular patterns of activities that people of Ghadames are experiencing to adapt themselves in such environments; these day to day activities are clearly dictated by the outdoor climate.

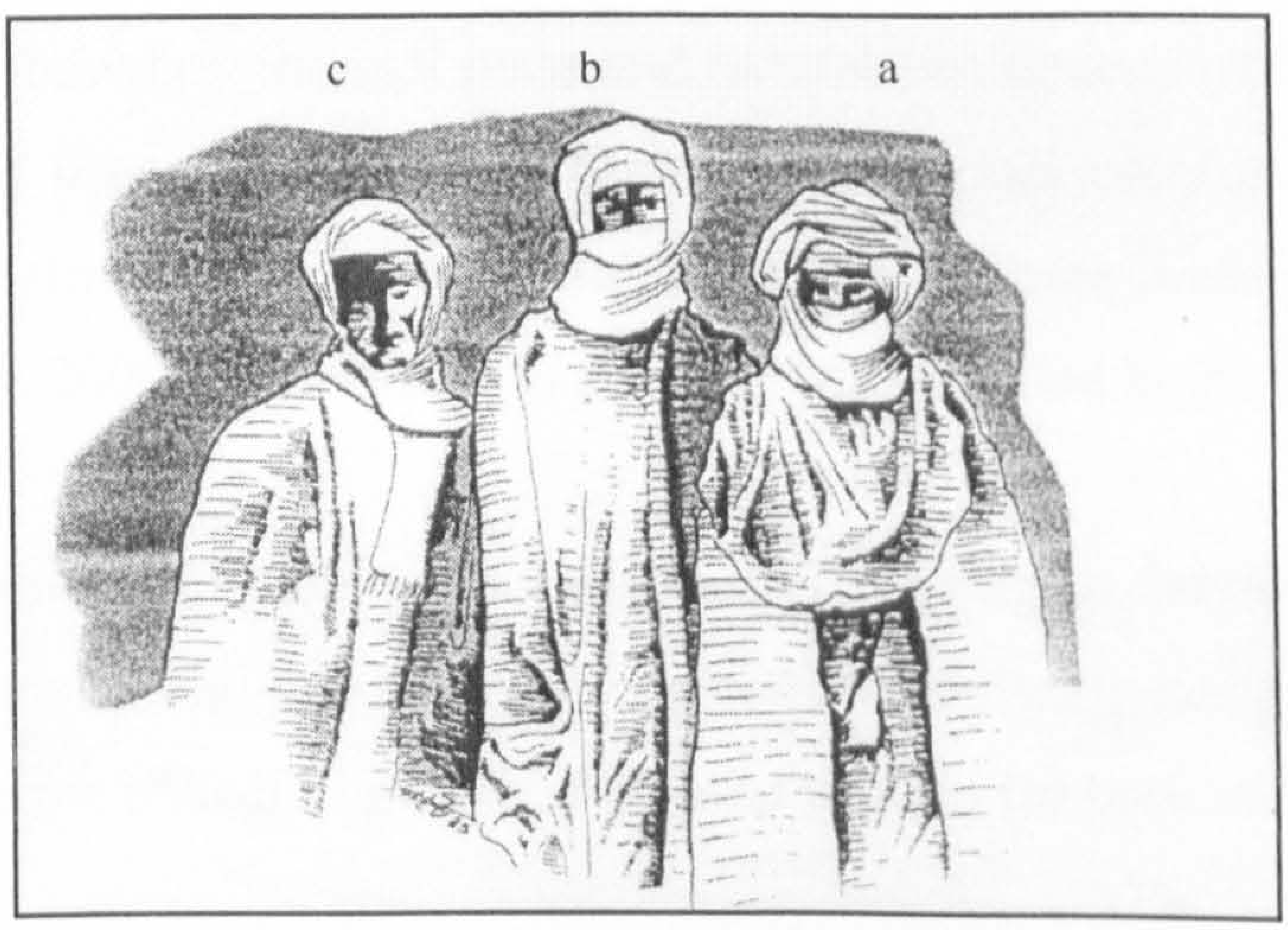


Figure 8.9:

This sketch (a)shows the clothing warn by the men folk of Taureq (a), Tebu (b) and Ghadamsi (c). Such covering are adaptation to the climatic condition of the outside areas (i.e. desert, sandstone) and wind bearing dust. That is the reason behind covering almost their faces eccept for their eyes.

Figure 8.10:

This sketch shows the faces are not fully covered because these people are mainly living in the coastal areas (i.e. Jabel Nafusa, near Tripoli). They normally wear 'jared' for successful adaptation,

8.2.7 Resume

In order to understand the impact of the outdoor climate and acclimatisation on human perception of thermal comfort, this section therefore has been addressed (8.2). It highlights the main social aspects such as; religion, life style, social structure, working patterns, and diet and activity levels of the residents in Ghadames region. All of these issues have been discussed and tested in terms of thermal comfort, which based on the assessment carried out from field survey in the summer season 1997. All of the results that have been used are collected from the subjective survey in Ghadames based on the questionnaires and Author's reviewing.

The main argument in this section is that social aspects together with the disposition of traditional building forms have been effected significantly by the outdoor climate. Both types of buildings (old and new) could achieve thermal comfort levels of their occupants, in which both involve with adaptation. For instance, in the old buildings it is based on thermal mass and natural ventilation, while in the new buildings it is based on uses of AC units. The human thermal comfort was measured using the human acclimatisation. The initial discussion of these findings has been presented in Ealiwa et al (2000) paper which is going to be published in the Room Vent' 2000 conference.

However, Table 8.1, as an example, highlights the direct and indirect implication of the outside and inside climate on both the building design and human climate responses in terms of sociological and cultural aspects for both old and new buildings.

Table 8.1: Sociological and cultural direct and indirect implication of outside and inside climate on both building design and human responses.

Sociological and Cultural Aspects for both Vernacular and Contemporary Buildings.	**Direct impact on building climate response (design).**	**Direct impact on human climate response; i.e. response to both outdoor and indoor climate in terms of thermal comfort requirements.**	**Indirect impact on human climate response through building design.**
1-Religion; In terms of Islamic roles. • Privacy. • Sex Segregation roles. • Security level.	Yes, such as on town planning; • Public. • Semi-public. • Private.	No impact.	Yes, such as; • Behaviour. • Dressing uniform.
2-Life style. -Daily activities locations.	Yes, on interior design of each building to provide sufficient and controlling light and airmovement to minimise the solar radiation. -Preventing solar radiation and over-heating. -Providing shaded places, i.e. alley-ways, narrow and covering streets, etc.	Yes, such as: • According to season and time, i.e. morning, mid-day or night. • Acclimatisation by dividing the occupants activities accordingly.	Yes, such as: • Furniture. • Public squares for ceremonial occasion and social celebrations.
3- Social structure. • Identity and Sensitivity of each Society. • Neighbourhood relationship.	Yes, based on past experience of the vernacular design elements. • The image and functional aspects of each society, for example; Courtyard location; Thickness of the exterior walls; Ventilation system; Light of the buildings. • Orientation of the buildings. • Compactness of the buildings. • Façade of each building. • Colour plaster of each surface. • Building materials. Foliage of plants or trees and using green areas to provide pleasing atmosphere.	Constituent element for development approach. • Prevailing the hot wind and solar radiation by considering; -Wind direction. -Location and size of openings. - Allowing the cool-night breeze into each building.	Yes, the main characteristic features are; -Spiritual. -Material. -Intellectual. - Emotional.
4- Working Patterns -Daily activities	No impact.	Yes, such as: • According to season and time, i.e. morning, mid-day or night. • Adapting their daily programs according to the sunrise and sunset.	Yes.
5- Clothing; conscious action. -It needs to calculate the clo. value. -Uniform layer of insulation of skin by; • Evaporation. • Absorb or Moisture.	No impact.	• According to season and time, i.e. morning, mid-day or night. • Adapting their clothing according to the outside climate condition, e.g. if there is dust like in desert regions.	Yes; such as; • Dressing layer. • Behaviour.
6- Diet -Daily meals. -Siestas.	No impact.	• According to season and time. • Adapting their daily programs according to the outside climate	Yes; habitation and lifestyle.
7- Activity level -It needs to calculate the metabolic rate. -Physical actions. -Basic needs.	Yes, according to the type of the place; • Public. • Semi-public. • Private.	• According to season and time, i.e. morning, mid-day or night. • Acclimatisation by dividing the occupants activities accordingly.	Yes, such as; • Behaviour. • Actions. • Power and energy.

8.3 Conclusions

This chapter has discussed the impact of the outdoor climate and personal acclimatisation on the human perception of thermal comfort. This was supported by the field survey carried out in the summer season 1997 and 1998, in the typical hot-dry climate of Ghadames oasis, Libya. In the context of what was mentioned earlier, the following conclusions can be drawn:

1. The outside climate was clearly an important parameter, influencing both human perception and building design in old and in new buildings.
2. Thermal adaptation is a reaction of the human-being to a specific climate, which is largely depends upon the social and personal acclimatisation. These factors have a much greater influence and should therefore be the focus of future research and development in this area, to include religion, life style, socio-cultural incentive, working patterns, clothing level, diet, and activity level. The satisfaction of thermal comfort is based on the experiences and the human thermal adaptation. Table 8.2 presents the evaluation of the important results of the implication of climate on both building design and human response in terms of the social and personal acclimatisation. This evaluation is based on Table 8.1 and previous analysis of these aspects.

Table 8.2: Evaluation of the importance of the climate implication on both building and human in terms of the social and personal acclimatisation.

Social and personal acclimatisation	Building design	Human response
1- Religion.	♦	◇
2- Life style.	♦	♦
3- Socio-cultural Incentive.	♦	♦
4- Working Patterns.	◇	•
5- Clothing level.	•	♦
6- Diet.	○	♦
7- Activity level.	•	♦

Where the scaling is;
♦ Very Important.
• Important.
○ Slightly Important.
◇ Not Important.

3. It is recommended that for future building design in environments like Ghadames, designers should benefit from local knowledge of the traditional design. It can offer valuable lessons in the optimisation of the internal design temperatures for the new building designs, and help people to adapt to their climate, e.g. ability to go outside during the hottest time (2-4 PM), effect on way of people's life style.

Chapter Nine:

DEVELOPING THE PROCESS TOWARDS THERMAL COMFORT AND PREFERENCE

"The traditional model house provides shelter from extremes of heat, dust and rain whilst modifying outside conditions to provide thermal comfort inside"
(Michell and Bevan, 1992: 15).

9.1 Introduction

Many researchers argue that, ignoring important cultural, climate, social factors, which are contextual dimensions of comfort, could lead to an exaggeration of the need for air-conditioning. de Dear et al (1998) have suggested that one of the predictions of the adaptive hypothesis is that people living in warm climate zones prefer indoor temperatures to be warmer than people whom are living in cold climate zones. Adaptive thermal comfort, which considers these factors, proved to be valid to measure thermal comfort in these environments as explained in chapter 7. By contrast, Fanger's comfort model, which does not recognise the adaptation factors, cannot be used without modification, to measure thermal comfort in such environments. This explains the discrepancy between the predicted neutral temperature of the adaptive model and Fanger's model in NV buildings, which will be addressed in this chapter.

Therefore, the main objectives of this chapter are;

a) To predict the neutral temperature, using both adaptive and Fanger's thermal comfort models in both traditional and contemporary buildings.
b) To propose a modified PMV model which can be used to predict thermal comfort in traditional NV buildings.
c) To measure the effect of preference of the occupants on the adaptive models and the thermal sensation.

9.2 Comparison between the Hypotheses of PMV and Adaptive models

The previous chapter showed that the outdoor climate has an effect on occupants' thermal comfort perception. This supports the hypothesis of the adaptive thermal comfort model that dependence of indoor neutrality on outdoor climate, may be due to behavioural adjustments that directly affect the heat balance. In fact, not only changing clothes according to the season could attribute these behavioural adjustments to a wide range of temperature, but also there are other factors in which the occupants adapt to the environment, as explained in the previous chapter.

Many commentators like Auliciems (1989) and Nicol (1993) state that the hypotheses of both Fanger's PMV and adaptive models are irreconcilable. de Dear et al (1998) have stated that "the simplistic cause-and-effect approach embodied in the PMV approach is not so easily applied to the more complex environments within real buildings populated by real occupants as opposed to subjects". It has also been stated by Brager et al (1998: p83-96) from their literature review on the topic of thermal comfort, that "the adaptive and PMV approaches to modelling thermal comfort are complementary, rather than contradictory". At some level, Brager et al (1998) and de Dear et al (1998) have suggested that the PMV model can also be considered as partially adaptive in the behavioural sense, since it acknowledges the effects of behavioural adjustments made by occupants to thermal environmental parameters, clothing, and metabolic rate. They consider that a variable indoor temperature can successfully combine features of both the PMV and adaptive models by incorporating behavioural, physiological, and psychological models of thermal adaptation. The neutrality predicted by the PMV model for a given building and its occupants, could be expected to show some dependence on outdoor climate. In other words, while the earlier adaptive model describes an empirical relationship between neutral temperatures and exposures to both the indoor and outdoor climates, it is unable to articulate the underlying causal relationships.

Figure 9.1 shows the comparison between the parameters of both PMV and adaptive models. It illustrates that the adaptive model, which is based on a homogenous environment ($t_{in} \simeq t_g \simeq t_{mr}$), with low air movement and sedentary activity level, considers the physical and personal parameters. In addition, this model involves the outside air temperature, as well as the human behaviour and their interaction with the environment, such as social aspects and their personal acclimatisation (as described in the previous chapter). These considerations of the adaptive model, in fact, make it valid to assess thermal comfort in such an environment without modification since the PMV model does not account for the feedback, as the adaptation approach does. This chapter will develop a new process towards thermal comfort by combining these models through the following sections.

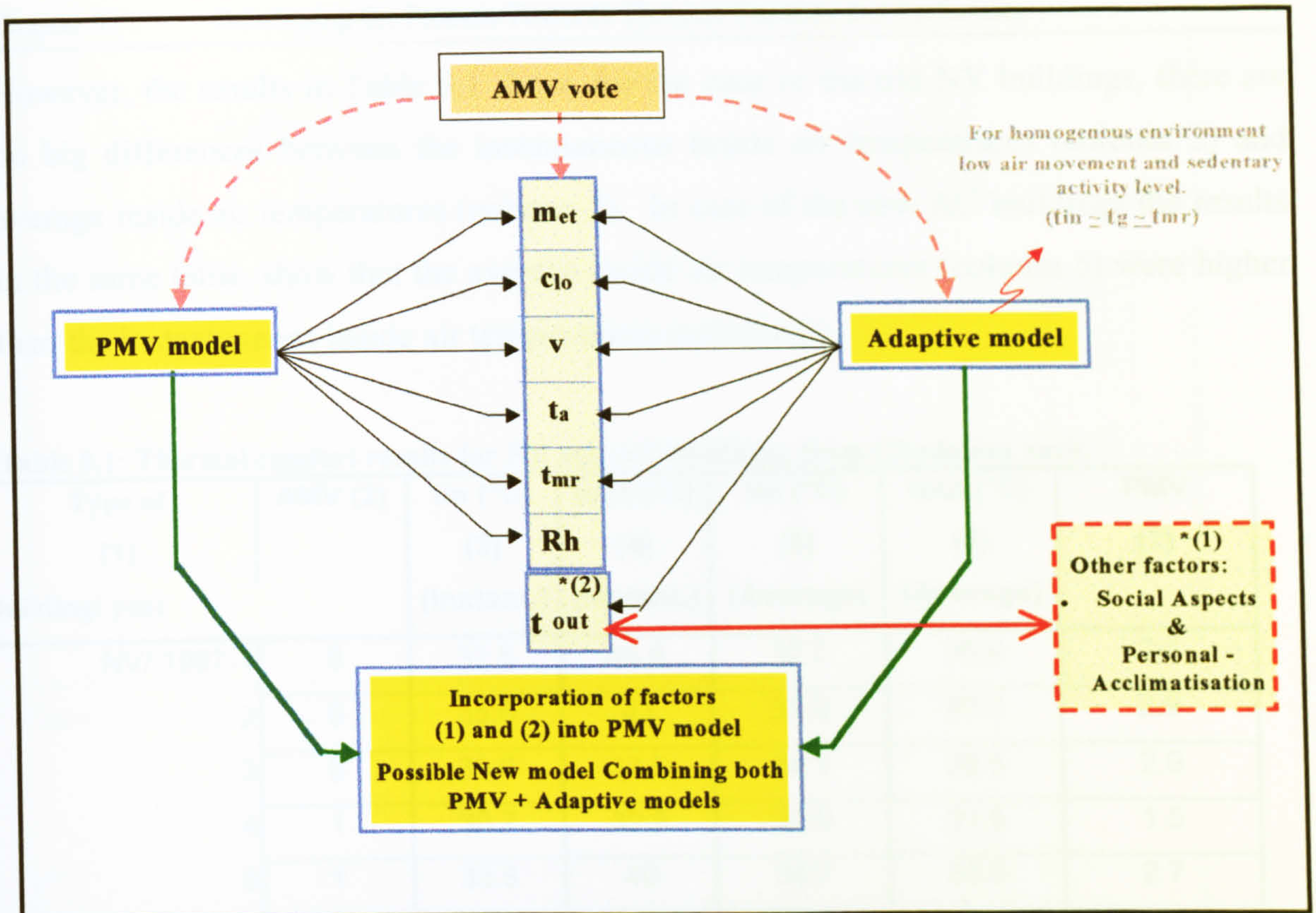


Figure 9.1: Possible new thermal comfort model combing both PMV and adaptive models.

9.2.1 Relationship between PMV and Air-temperatures

The adaptive model of thermal comfort would have particular relevance to naturally ventilated buildings and other situations in which building occupants have some degree of indoor climatic control. The thermal comfort zone could be determined from the 7-point ASHRAE sensation scale, in which the middle point represents the neutrality of the occupants' feeling (i.e. PMV = -0.5, 0, +0.5). Referring to chapters 7 and 8, the results from the traditional NV buildings show some discrepancies between AMV and PMV, which concludes that the PMV model is invalid to assess the thermal comfort without modification. In order to make the questionnaire understandable for the residents in Ghadames in Libya as a result of difficulties involved in translating the questionnaires from English to Arabic, the comfort zone was deemed to have been achieved when PMV = -1, 0, +1. Table 9.1 presents thermal comfort results when subjects felt neutral for 5 NV buildings and 6 AC buildings, from the field survey conducted at Ghadames in Libya. It also presents the PMV values based on the average inside and outside air temperatures.

However, the results in Table 9.1 show, for the case of the old NV buildings, there are no big differences between the instantaneous inside air temperatures (column 3) and average inside air temperatures (column 5). In case of the new AC buildings the results in the same table, show that the average inside air temperatures (column 5) were higher than the instantaneous inside air temperatures (column 3).

Table 9.1: Thermal comfort results for NV and AC buildings, from Ghadames oasis.

Type of (1) Building/ year	AMV (2)	tin (°C) (3) (Instant.)	tout (°C) (4) (Instant.)	tin (°C) (5) (Average)	tout (°C) (6) (Average)	PMV (7)
NV/ 1997-1	0	32.5	45.6	32.0	36.9	2.6
2	0	35.6	43	35.3	40.0	2.9
3	0	33.6	37.5	34.1	38.5	2.9
4	1	30.7	32.8	30.8	31.5	1.5
5	1	33.8	40	34.7	39.0	2.7
AC/ 1998-1	1	31.5	39.7	34.2	40.3	1.7
2	0	28	36.2	32.0	37.9	0.7
3	0	26.6	31.2	30.8	35.6	0.4
4	0	25.5	42.2	28.5	36.2	-0.4
5	1	30	39.1	32.1	38.7	1.8
6	0	28.8	39.8	31.9	39.1	0.4

Figure 9.2 shows the linear regression of PMV values as function of average inside air temperature for the traditional NV buildings only, where the whole linear regression is above the thermal comfort zone. Figure 9.3 shows the same correlation, but for the new AC buildings, where most of the linear regression is within the comfort zone. Figure 9.2 also suggests that when the inside air temperature (tin) approaches the skin temperature (i.e. standard of 34°C), that means the metabolic rate is dissipated mainly by evaporation or storage, leading to a new regime in heat transfer in terms of thermal comfort perception. This could explain why the PMV model could not work in the case of the old NV buildings, when tin $\geqslant$ 30.8°C, which is the skin temperature minus 3°C, as illustrated in Table 9.1. In this range the PMV model does not work without modification.

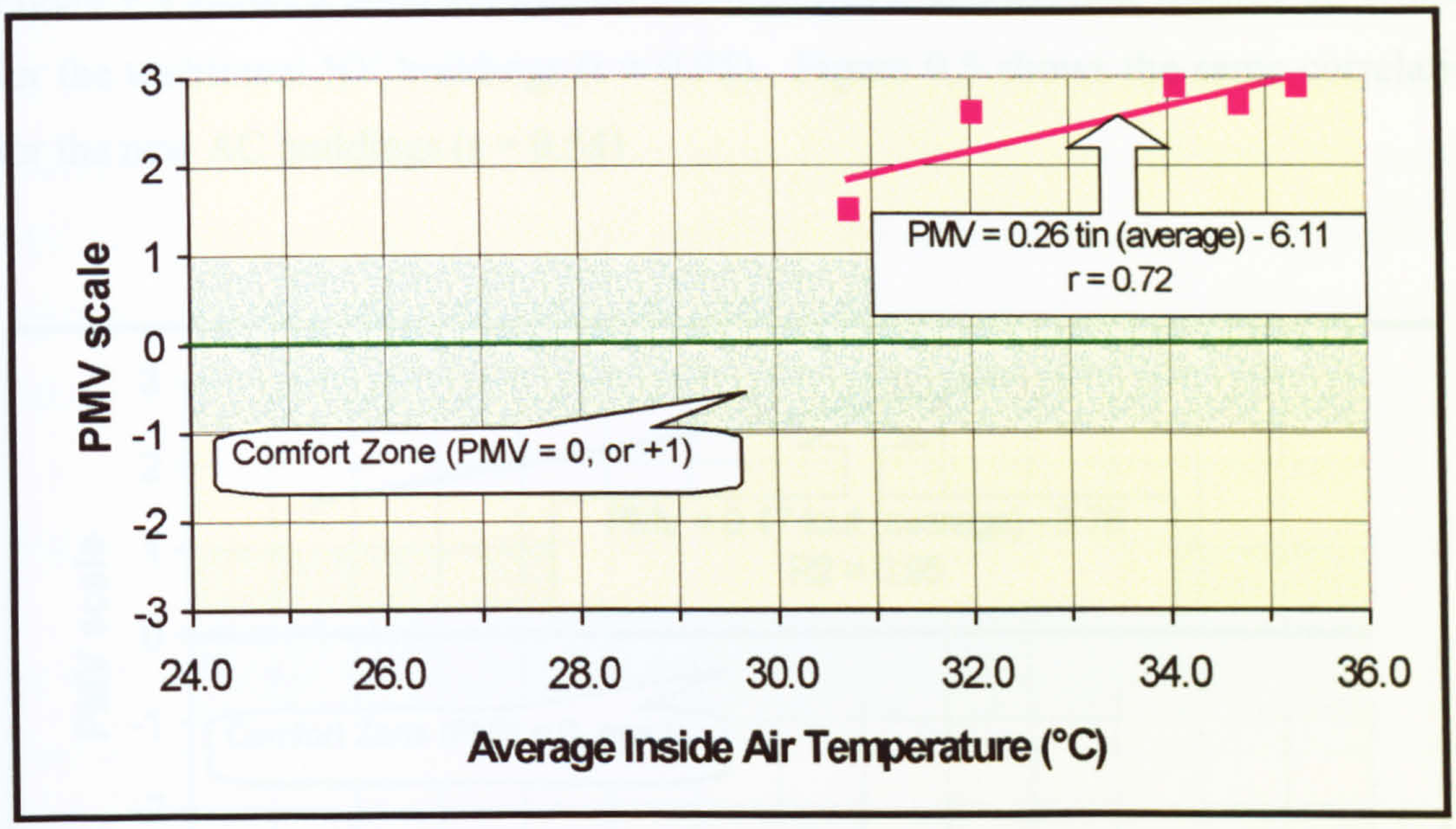


Figure 9.2: PMV versus average inside air temperature in traditional NV buildings of Ghadames.

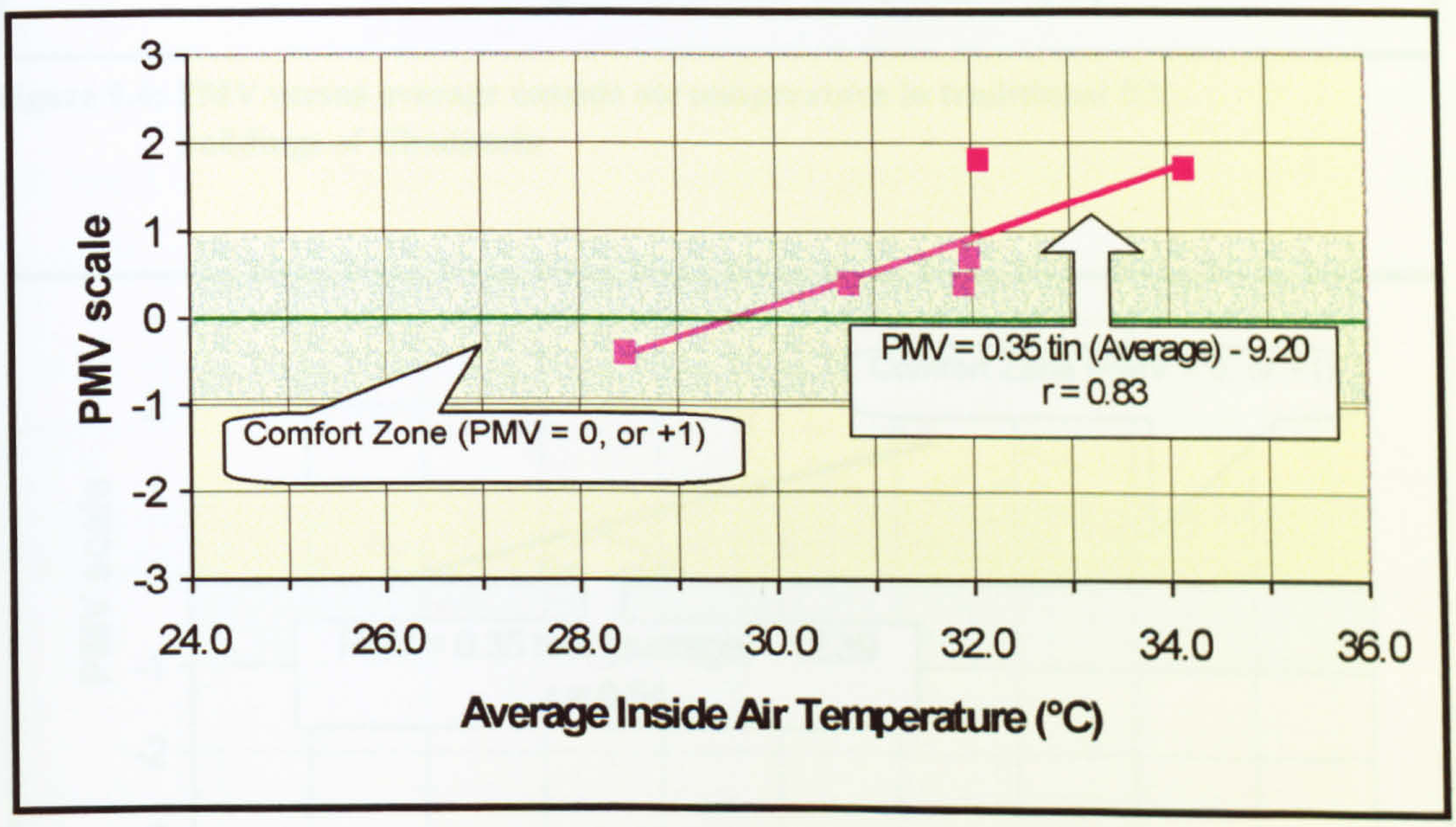


Figure 9.3: PMV versus average inside air temperature in new AC buildings of Ghadames.

Figure 9.4 shows a good correlation between PMV and average outside air temperature for the traditional NV buildings (r = 0.95). Figure 9.5 shows the same correlation, but for the new AC buildings (r = 0.54)

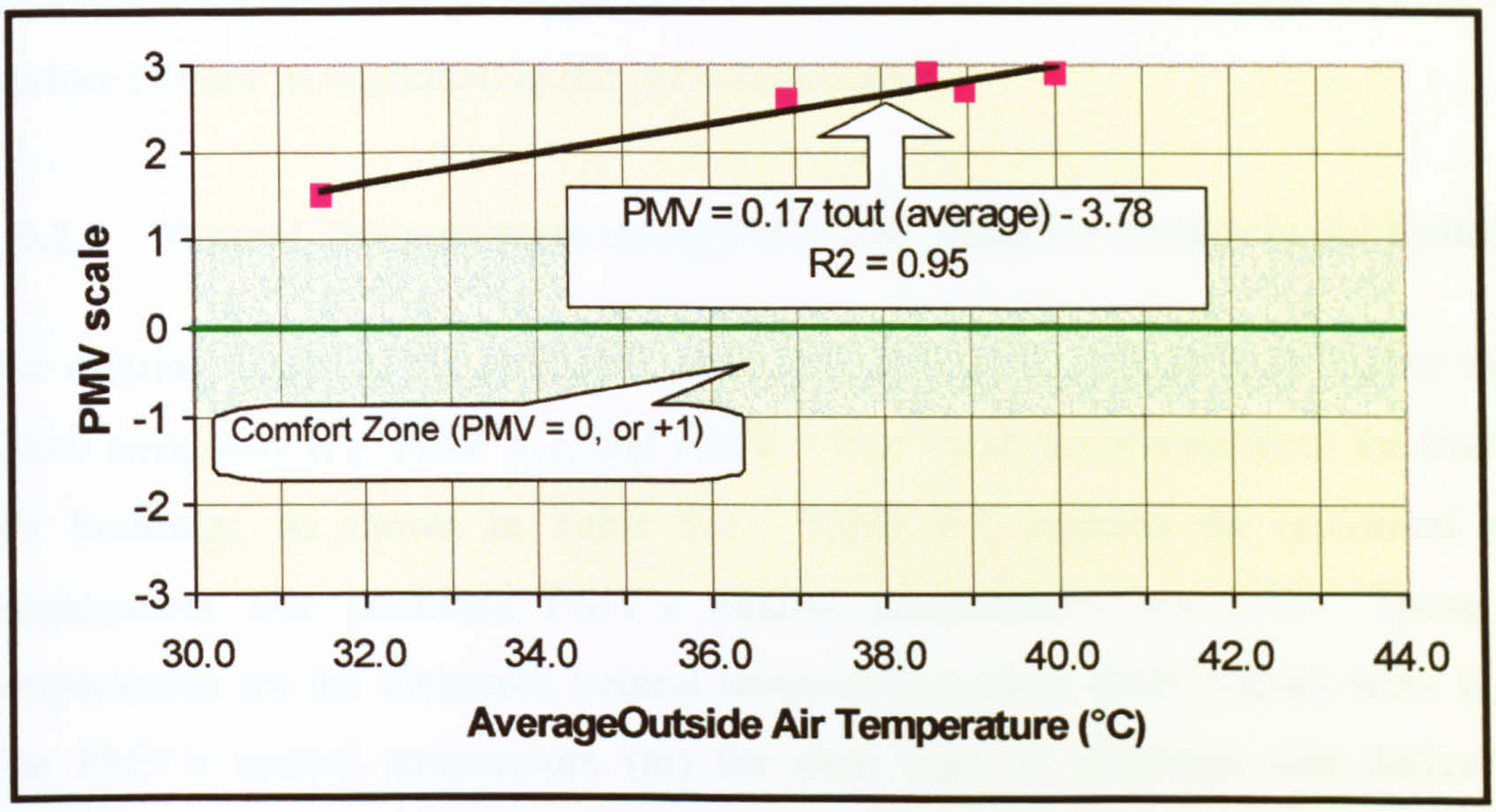


Figure 9.4: PMV versus average outside air temperature in traditional NV buildings of Ghadames.

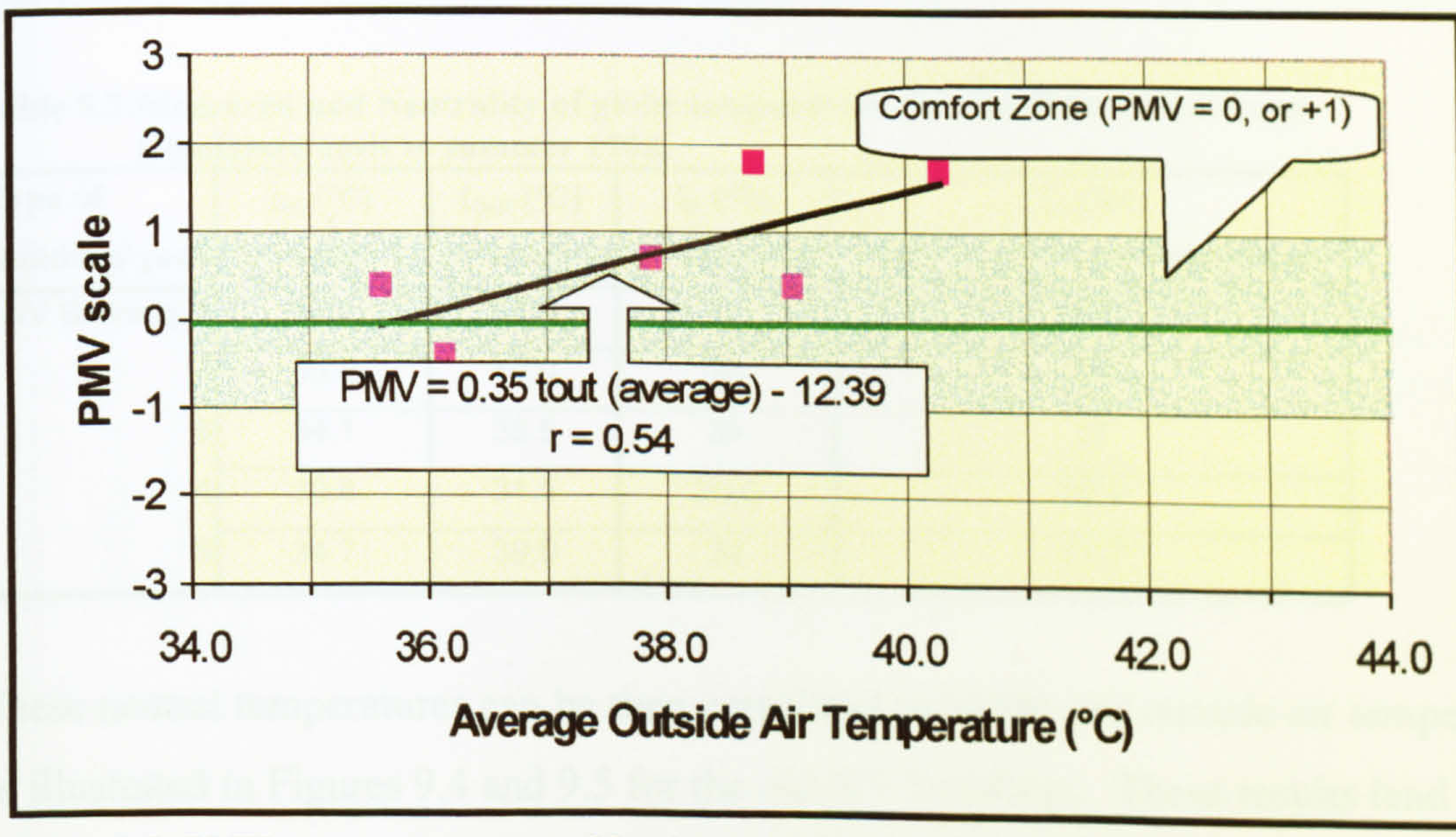


Figure 9.5: PMV versus average outside air temperature in new AC buildings of Ghadames.

The PMV values are clearly above the comfort zone for the case of traditional NV buildings, and they are within the comfort zone for the case of new AC buildings. PMV values are strongly correlated with the inside and outside air temperatures, in particular with reference to Figure 9.4, which shows that PMV values depend on the outdoor climate as explained in the previous chapter.

9.2.2 Neutral Temperatures using PMV and Adaptive models in old buildings

The existing values of the predicted mean vote values are significantly higher than the actual mean vote (i.e. PMV $\geqslant 2$, and AMV = 0 or 1) of the occupants in the traditional NV buildings, as shown in Table 9.1. Table 9.2 contains the measured neutral temperatures and predicted PMV's neutral temperatures for NV. These globe temperatures are the measured neutral temperatures since AMV values were 0 or +1. The PMV's neutral temperature (tn) for each type of buildings was derived from inputting the building's basic parameters (i.e. v, Rh, clo, met) into the PMV model, and then iterating for different globe temperatures until reaching thermal indoor neutrality (i.e. PMV = 0).

Table 9.2:Measured and Neutrality of globe temperature for the PMV model from Ghadames oasis in summer 1998.

Type of Building/ year	t_{in} (°C) (average.)	t_{out} (°C) (average.)	t_n (°C) (measured)	t_n (°C) (PMV' s neutral temperature)
NV Building-1	32.0	36.9	33	18.7
2	35.3	40.0	35	16.4
3	34.1	38.5	34	17
4	30.8	31.5	30.5	22.2
5	34.7	39.0	34	17.7

These neutral temperatures can be then correlated to inside and outside air temperatures, as illustrated in Figures 9.4 and 9.5 for the old NV buildings. These results lend support to the adaptive hypothesis, as de Dear et al (1998) have stated that:

> "in the background to predict thermal adaptation to the outdoor climate, as well as the indoor. If valid, this hypothesis can explain the tendency for indoor neutrality to increase as outdoor climate becomes warmer, and would predict this relationship to be stronger in building where people are more connected to the natural swings of the outdoor climate (i.e. NV buildings)".

To achieve the neutral PMV value (PMV = 0) for the NV buildings at maximum inside air temperature of 35.5°C, the neutral temperature was reduced to 16°C from 32°C. This shows that PMV value of 3 is equivalent to ƛtn of 16°C. Also, the neutrality could be achieved for the same type of buildings at minimum inside air temperature of 30.5°C, by reducing the neutral temperature to 21°C from 28.5°C. This shows that the PMV value of 1.5 is equivalent to ƛtn of 7.5°C, see Figure 9.6. Therefore, the average offset value of PMV is 2.25, which is equivalent to an increase of 11.75°C in neutral temperature. However, if PMV = 1 (as explained in section 9.2.1) is assumed to be the value for prediction of human thermal neutrality, then the ƛPMV equals 0.5, which is equivalent to ƛtn of zero, when tin = 30.5°C. Similarly, when inside air temperature is 35.5°C, the ƛPMV equals 2 which is equivalent to ƛtn of 9°C. This gives an average ƛPMV of 1.25 or ƛtn of 4.5°C. It may be concluded that for design purposes the average PMV value should be reduced by 1.25 or an increase of the neutral temperature by 4.5°C, if the PMV model should be used in this environment. This offset value in PMV is valid when inside air temperature ranges from 30.5°C to 35.5°C.

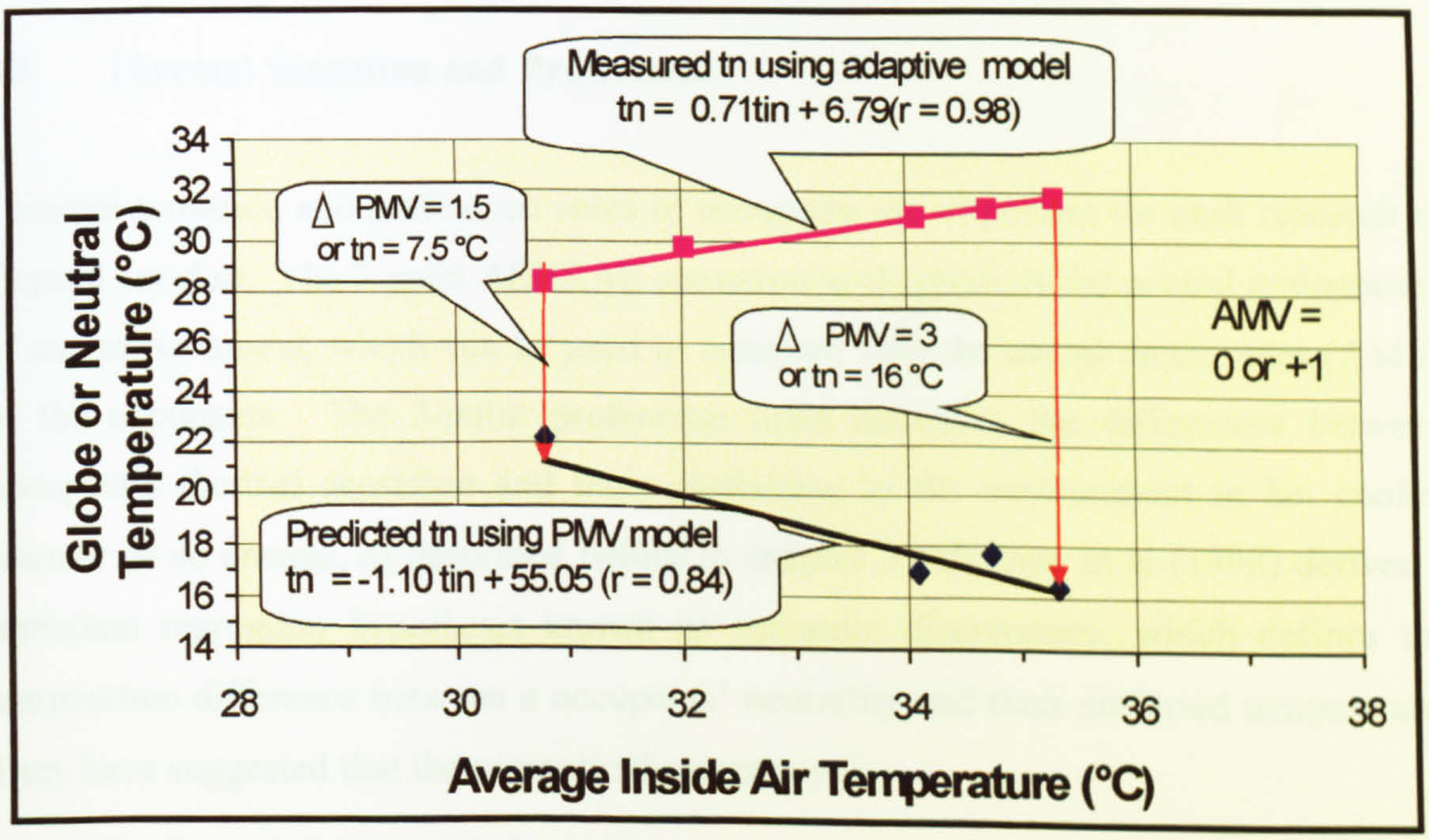


Figure 9.6: Comparison between PMV model's neutral temperature and the adaptive model's neutral temperature for a range of inside air temperature, in the traditional NV Buildings of Ghadames, Libya.

Similarly, Figure 9.7 shows the same manner of relationships between PMV model's neutral temperature and the adaptive model's neutral temperature, but as a function of outside air temperature.

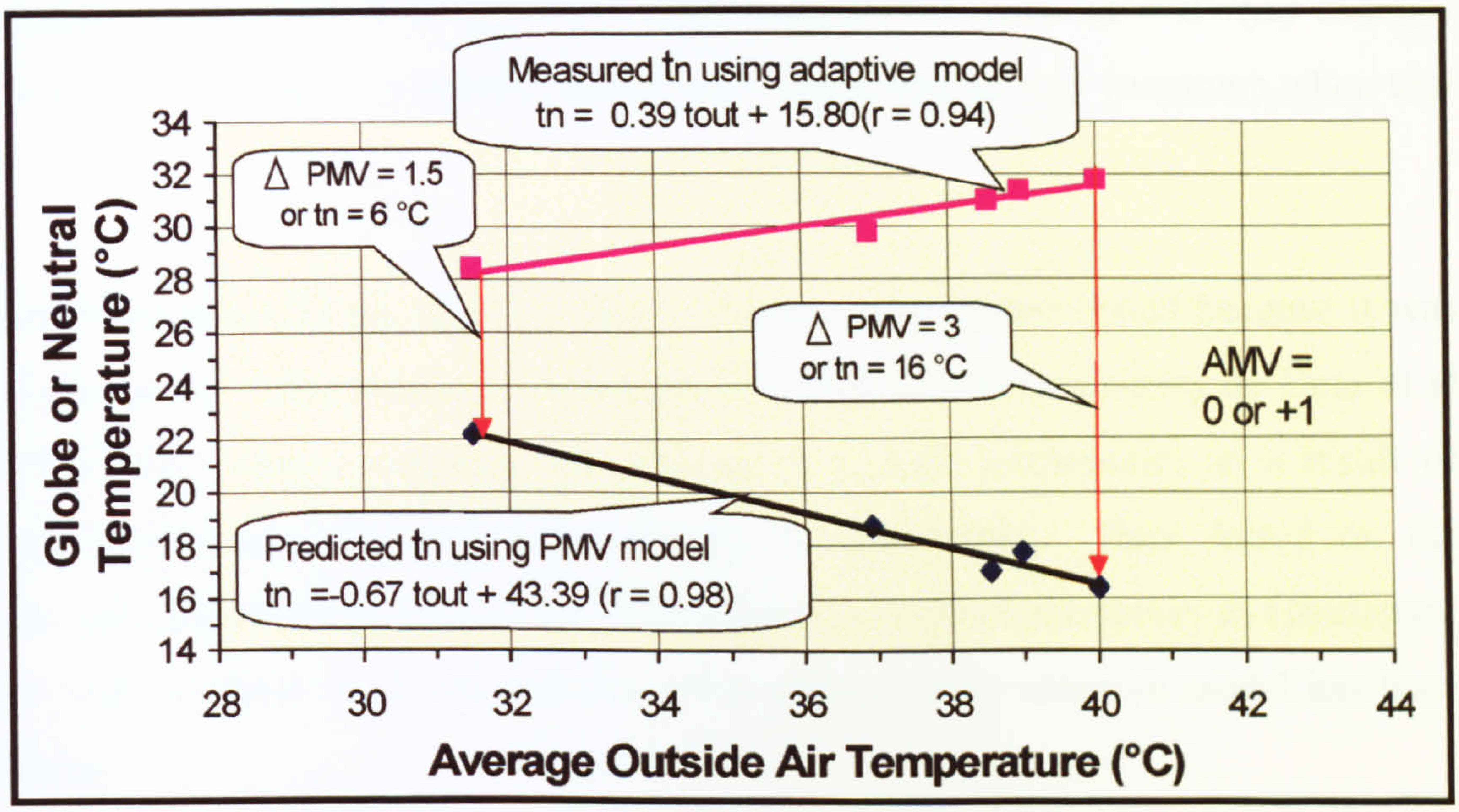


***Figure 9.7:** Comparison between PMV model's neutral temperature and the adaptive model's neutral temperature for a range of outside air temperature, in the traditional NV Buildings of Ghadames, Libya.*

9.3 Thermal Sensation and Preference

Thermal sensation and preference votes of occupants are important for each research of thermal comfort. The 7-point ASHRAE sensation scale predicts the neutral temperature of any environment, which can be used to compare with the actual mean votes (AMV) of the occupants. The 3-point preference scale describes the differences between occupant's thermal sensation and their preference to the environment to be: cooler, warmer or no change, as described before in chapter 3. de Dear et al (1998) derived a statistical regression hypothesis known as semantic discrepancy, which defines the temperature difference between a occupants' neutrality and their preferred temperature. They have suggested that the semantic discrepancy is:

$$sd = -0.95 + 0.07\ \%\ tout \longrightarrow (9.1)$$

where; sd is the semantic discrepancy in °C and tout is the outside air temperature in °C.

They used data extracted from buildings in their database, in which they examined the differences between building occupants' neutrality and their preferred indoor temperatures. They examined this regression within a range of mean outside temperatures from –5°C to 35°C. This regression models gave sd = 0 (no change) when tout = 13.6°C, sd = +1 (cooler) when tout = 28°C and sd = -1 (warmer) when tout = 0°C.

Due to the shortage of data, this hypothesis has not been further tested because it was beyond the scope of this research. Therefore, the equation developed by de Dear et al (1998) has been used to estimate the changes in neutral temperature as a result of preferred temperatures (if any) expressed by the occupants. Thus, based on the available measured average outside air temperatures from the field survey in Ghadames, together with equation (9.1), the semantic discrepancy of the adaptive model has been determined.

The results indicated that occupants of both types of buildings preferred cooler environment, as shown in Figure 9.8. This figure shows that 70% of the occupants in the AC buildings preferred to be cooler and only 30% wanted no change. However, in NV buildings 40% of the occupants preferred to be cooler and 60% of them wanted no change. These results indicated that the preference votes of the occupants have a significant effect on the adaptive neutrality in the AC buildings. Since the majority of occupants in the old NV buildings wanted no change in their indoor thermal environments, the sd equation has not been applied for this type of building.

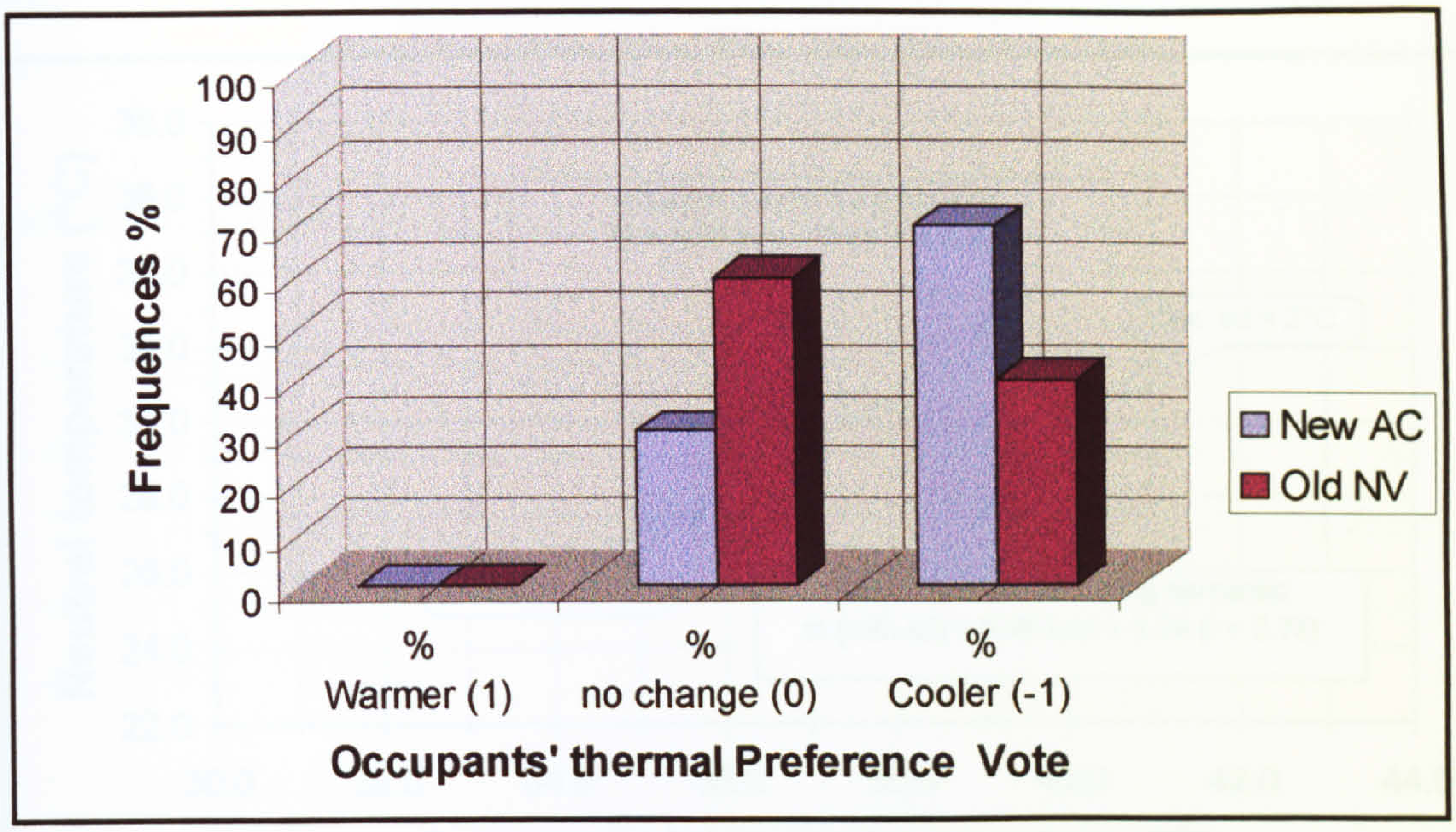


Figure 9.8: Thermal preference of the occupants for both NV and AC buildings *in Ghadames oasis, summer 1998.*

Figure 9.9 shows the measured neutral temperature for a range of outdoor air temperatures, using equation (9.1) in new buildings including semantic effect. This figure shows that correcting the AC building' optimum temperature due to occupants' preference has the effect of decreasing the occupants' sensitivity to average outside air temperature. According to semantic discrepancy hypothesis (equation 9.1), the results indicate that the occupants of AC buildings in Ghadames registered a temperature preference of an average of 1.7°C cooler than their thermal neutrality even though the AC was on. Figure 9.10 compares the effect of incorporating the semantic into the adaptive model with the PMV model prediction when comparing the neutral temperature (tn) with the average outside temperature.

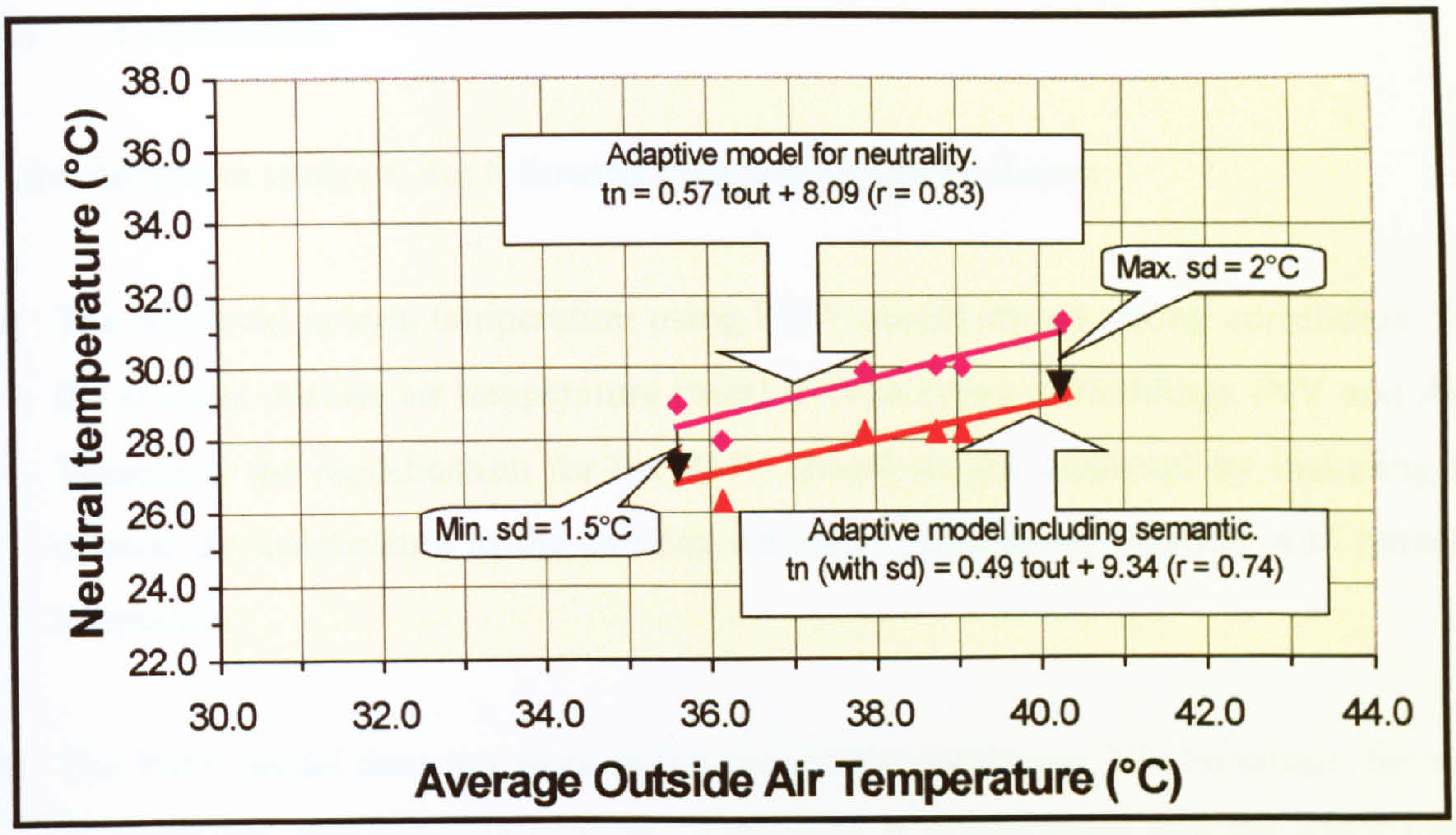


Figure 9.9: Thermal sensation vs. preference. The effect of the semantic discrepancy adaptive neutrality in the AC buildings in summer season at Ghadames oasis, to decrease the occupants' sensitivity to average outside air temperature.

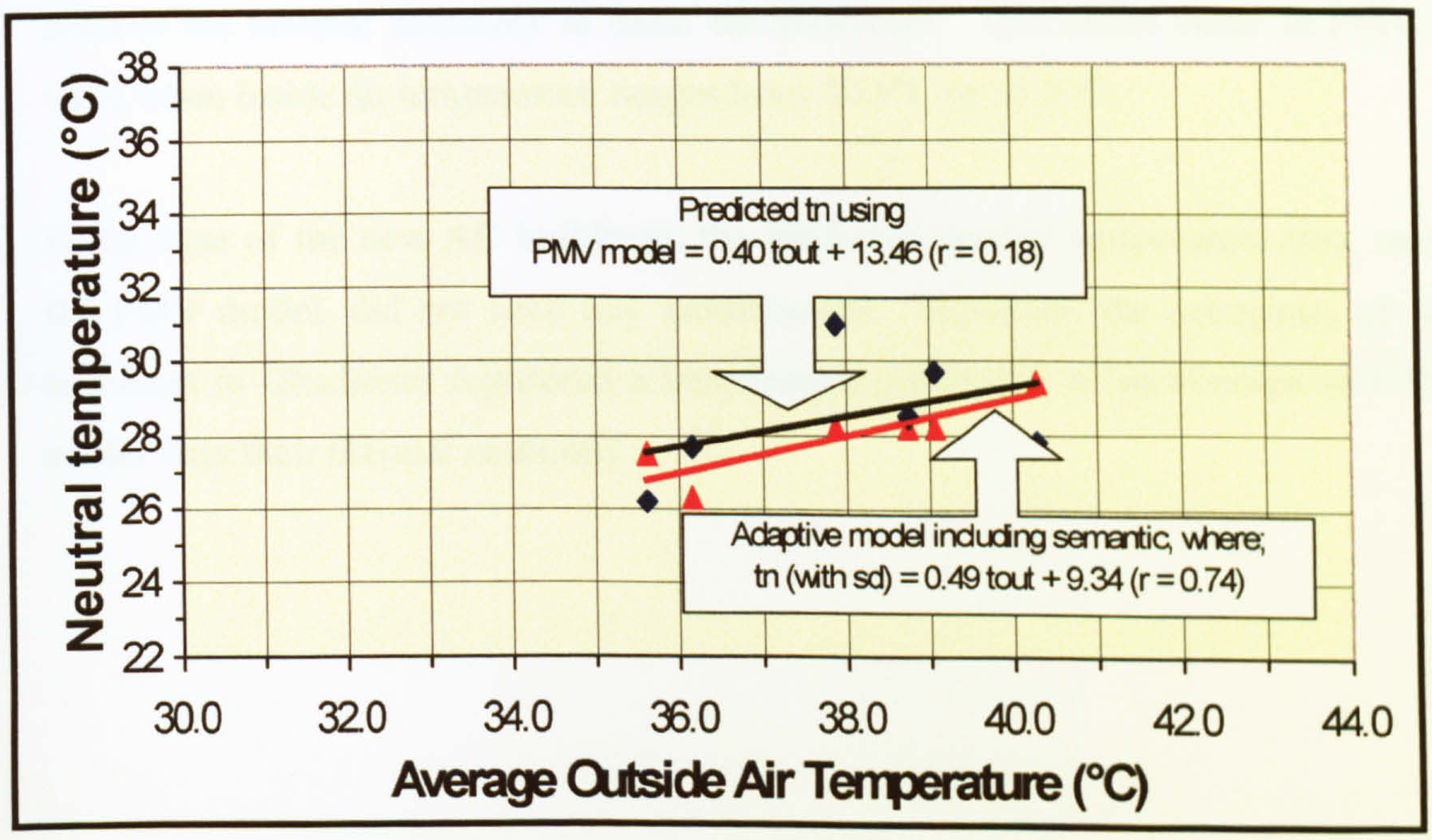


Figure 9.10: The PMV model vs. the adaptive model including semantic discrepancy in the AC buildings in summer season at Ghadames oasis, Libya.

9.4 Conclusions

From the above analysis, the following conclusions can be drawn:

a) The predicted neutral temperature using PMV model shows strong correlation with the average outside air temperature (tout) in both types of buildings (NV and AC). Therefore, the modification for the PMV model maybe achieved by including the outside air temperature to the existing six basic parameters, together with personal adaptation.

b) The PMV model does not work in the case of the traditional NV buildings, for such environment, without modification. Therefore, it is suggested that the PMV value, using the existing Fanger's model, should be reduced by an average ΔPMV of 1.25, or the PMV model's neutral temperature should be increased by Δtn of 4.5°C to achieve the thermal neutrality in these environments. This offset value in PMV is valid when inside air temperature ranges from 30.5°C to 35.5°C.

c) In the case of the new AC buildings; the predicted neutral temperature (tn), using the PMV model, did not need any modification. However, the occupants of AC buildings in Ghadames registered a temperature preference of an average of 1.7°C cooler than their thermal neutrality.

Chapter Ten:

Conclusions and Recommendations for Further Research

"Life is the art of drawing sufficient conclusions from insufficient premises".
Butler (1894), as quoted by Oseland (1997).

10.1 Conclusions

This research work has investigated field survey in human thermal comfort for both old traditional NV buildings and new contemporary AC buildings in the summer seasons 1997 and 1998, in the typical hot-dry climate of Ghadames oasis, Libya. Since no other research workers have conducted such studies in North African regions, this present work will complement the existing knowledge of thermal comfort field around the world giving it uniqueness in terms of knowledge contribution in this field. These results obtained in the field survey in Ghadames have been accepted as reasonable and therefore may be used as input data in further thermal comfort work. The following conclusions can be drawn:

1. The overall subjective results during the whole summer season (i.e. how they feel generally?) from 60 buildings (30 old; 30 new) suggest that the of the majority occupants in the traditional buildings were in general thermally more comfortable than who are living in the contemporary buildings. Traditional NV buildings provide for their occupants a better indoor environment; hence 47% felt neutral, 85% reported being comfortable, and 70% wanted no change of their indoor environment. This compared with only 30% who felt neutral in the contemporary AC buildings, 50% who reported being uncomfortable, and 60% who wanted to change their indoor environment to be come cooler. In addition, the instantaneous (i.e. how they feel now?), the subjective results from 19 buildings (9 old; 10 new) suggest that their thermal sensation is more comfortable in the 9 old naturally ventilated buildings than in the 10 new air-conditioned buildings. For instance, in the old buildings, about 54% of the occupants felt neutral (0) and 8% felt hot (+3), compared to only 15% of the occupants felt neutral (0) and 33% felt hot (+3) in the new air-conditioned buildings.

2. The adaptive model works effectively for this hot/dry climate region. The performance of the adaptive method proposed appears to be successful for both types of buildings (9 traditional NV buildings, and 10 contemporary AC buildings). The collected field survey of this thesis, may consolidated with data from various world wide studies using Auliciems (1983) equation. The neutral temperatures were

30.6°C and 29.4°C for the traditional NV buildings and the contemporary AC buildings respectively. Such satisfaction of thermal comfort in this harsh climate at these high temperatures can be only achieved when it is based on acclimatisation effects and adaptation, together with past experiences. This confirms the effect of the outdoor climate on perception of thermal comfort. Building design, together with acclimatisation effects, can contribute to substantial savings in energy consumption in the modern AC buildings.

3. Fanger's PMV model in the form of ISO 7730 (1995) also succeeded to assess human thermal comfort in case of the modern AC buildings without modification. However, this model (i.e. PMV) was less successful to assess human thermal comfort in case of old NV buildings for the hot/dry climate region. Therefore, it is clearly in need of modifications in related to adaptive effects, which are suggested to be as follows: -

- To include the personal adaptation and outside air temperature to the existing six basic parameters, since these were proved to be important by influencing both human perception and building design especially in the traditional NV building.
- The PMV values should be reduced by an average ΔPMV of 1.25, or the PMV model's neutral temperature should be increased by Δtn of 4.5°C to achieve the thermal neutrality in these environments. This was based on the measurements collected from 9 old buildings and when inside air temperatures ranged from 30.5°C to 35.5°C.

4. The field-work demonstrated the importance of the accounting for the cultural; legal social and religious context in which researcher working. Therefore, to conduct a field survey in such environment as Ghadames region, the researcher should consider the following main problems: -

- accessibility; researcher needs to have enough ideas and information about the way of life, before contacting directly with them, i.e. their religion, culture, traditional uniform of clothing and activity levels etc.

- After selecting the participants and samples of buildings, it important to brief the subjects about the experimental project and questionnaire in more detail. The questionnaire has been translated into Arabic for the first time and by doing this the researcher might face some difficulties to translate these scientific concepts; Therefore he/she needs to be more calm and patient with the subjects. As well as he/she needs to explain the whole questionnaire in more details and how to fill or report their votes, after dividing participants into small groups, to avoid any miss-understanding of any question and to be sure that they are going to return the questionnaires back fully completed.

- Clearance from the project grant or university where the project is researching, then followed by a legal permission, when arriving to the case study location, from main Government Authorisation offices in Tripoli, and another prior-arrangement with the local Authority office in Ghadames to liaise their permission and introduce the file work to the local people in order to make them more co-operative.

10.2 Recommendations for Further Research

a) Extra measurement data in thermal comfort of different times of year in Ghadames, and from different regions in Libya (desert and coast regions), as well as from other countries that have same climate, are recommended. This will help to assess Fanger's model when PMV reaches a value of +2. In addition, neutral temperatures can be then calculated using adaptive models for such cool conditions. The information definitely will help to make more general conclusions and would contribute to make a new 'Global Standard' for assessment of thermal comfort in different climates including hot/dry regions. Additional validation is needed for the proposed modification of the PMV model for this climate and others.

b) The measurement of human thermal comfort in these environments can be complemented with the assessment of air quality perceived by the occupants, together with their performances in both domestic and non-domestic buildings.

c) Thermal adaptation is a reaction of the human-being to a specific climate, which largely depends upon environmental and behavioural adaptation. These factors have a considerable influence and should be the focus of future research and development, and include acclimatisation and socio-cultural issues, such as religion, life style, incentive, working patterns, clothing level, diet, and activity level, etc.

d) The co-ordination between urban planners, architects, thermal comfort modellers, together with occupants' past experience should be well established for providing comfortable environments with minimum energy consumption. Therefore it is recommended that future, in such hot/dry climate regions, designers should benefit from local knowledge of the traditional design. It can offer valuable lessons in the optimisation of the internal design temperatures for the new building designs. Similarly, building regulations and planning bye-laws should be reviewed critically to respond to the users' social and personal needs, as well as their thermal requirements.

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APPENDIX A:

Questionnaire, health and general form in English

An Investigation of Building Environment which Employ Natural Ventilation-Courtyard System in a Hot-arid Climate

Mansour Ali Ealiwa, Ph.D. Research student in Department of Building Studies, at De Montfort University, Leicester, UK. 16th. January. 1997

This field study/ project is being conducted by Mansour Ali Ealiwa, a Libyan Ph.D. research student in the School of Built Environment at De Montfort University UK. This survey is about the quality of the indoor environment and any effects that it may have on thermal comfort of residents living in this building. Therefore, I would be very grateful if you could fill in this questionnaire to assist me in knowing how much, or how little, you like thermal environment level of your building; is the courtyard important to be within the building; the level of natural ventilation; and some other factors of environment, which may be relevant to the thermal comfort of the building.

Through previous work of this kind it has been possible to recommend changes or guidelines for substantial improvement in such building environment. Consequently, the information you give the researcher will help him to become more aware of housing problems in hot-dry countries such as Libya, and make further recommendations. So, the success of this study depends mainly upon your assistance. Any information you given will of course be treated in the strictest confidence.

Thank you in advance for your co-operation and support

Mansour A. Ealiwa

SUBJECT CLOTHING DETAILS

Please Complete the following form as accurately as possible. If you have any queries please do not hesitate to ask your experimenter.

Type of Building: Courtyard Building .... Modern Building .... [✓]

Season: Summer .... Winter .... Date: ..... / .... / 1997

Name: ....

Gender: Male .... Female ..... [✓]

Date of Birth: ..... / .... / 199

Height: .... meters

Weight: .... Kg

Clothing Worn

Please give material type and make of the following garments that you are wearing.

Skirt or trouser Size: ....

Traditional Clothes: ....

....

Socks: ....

Pants: ....

Shoes - Uppers: ....

Shoes - Soles: ....

Comments: ....

....

....

APPLICATION TO TAKE PART IN THERMAL EXPERIMENTS

Please read the following carefully

Person may be considered unfit to do the experiment if:

- Under 4 years old.
- Have an infectious disease.
- Have a fever, suffer from fainting spells or dizziness.
- Have a mental disorder.
- Have a neurological disorder.
- Have an ear infection.
- Deafness or history of ear surgery.
- Blindness or other eye disease
- Notifiable occupational disease.
- History of coughing up, vomiting or passing blood.
- History of blood pressure or heart disease.
- Intermittent pain, blanching or numbness of fingers.
- Surgical operation within the last 6 months.
- Frostbite, hypothermia, hyperthermia, heat exhaustion or stroke and other heart disorders.
- Anal disorders (where rectal probes used).
- Asthma or other long term chest conditions.
- Blood clotting problems.

Name : ....
Age: ....
Are you in good health? Yes ...... No [✓]
If no, please explain: ....
....
Have you ever suffered from a serious illness or accident? Yes ...... No [✓]
If yes, please give particulars: ....
....
Are you at present under medical treatment? Yes ...... No [✓]
If yes, please give particulars: ....
....
Have you taken part in an experiment in this building on a previous occasion?
Yes ...... No [✓]

DECLARATION

I, ... hereby volunteer to be an experimental subject in thermal experiments during the period of .... 1997.

My replies to the above questions are correct to the best of my belief and I understand that they will be treated with the strictest confidence of the experimenter. The guide of the experiment has explained to me by the experimenter.

I understand that I may withdraw from the experiment at any time and that I am under no obligation to give reasons for withdrawal or to attend again for experimentation.

I undertake to obey the laboratory regulations and the instructions of the experiment regarding safety, subject only to my withdraw declared above.

Signature of Subject: .... Signature of Experimenter: ....

Date: .... Date: ....

QUESTIONNAIRE ONE: FOR RESIDENTS IN A COURTYARD BUILDING.

This section is considering for Summer Season only.

Residential Survey

- Name of Project: ....
- Name of Interviewer: ....
- Date: ....
- Block Number ....
- Orientation: ....
- Name of respondent (husband or wife or others):...
- Location: .... City .... Village .... New town

SECTION A: BACKGROUND INFORMATION

1. What is the size of your household? .... Male .... Female
2. What ages are the people in the houses? Adults ....
   Children (under 18) ....
3. How long have you lived in this neighbourhood? .... Year/s .... Months
4. How long have you lived in this building? .... Year/s .... Months
5. Are you the owner or renter of this building? .... Owner .... Renter
6. Do you have another building (in the new form)? Yes ...... No .... [✓]
   If yes, do you still live in it? Yes .... No ....
   If no, why do you not live in it? ....
   ....
7. How many hours per day do you normally spend in the building? .... hour(s)
8. How many floors are in your building? 1 ...... 2 .... 3 .... More ....
9. How many bedrooms are in your house? 1 2 3 If more than 3 how many? ....
10. How many toilets are in your house? 1 2 3
11. Do you have in your building any mechanical ventilation? Yes ..... No ..... [✓]
    What is it? (i.e. disk fans, selling fans, air-conditioning) ....
    and where? (i.e. Bedroom, Kitchen, etc.) ....
    any comments; ....

SECTION B : SOCIAL INTERACTION

Please rate your building on each of the following scales, when it is required, where 3 is the middle position:

1. How close do you think you are with your next door neighbours?

   Too close+ 1 2 3 4 5 -Too distant

2. How often do you talk to the persons next door?

   Every day+ 1 2 3 4 5 -Never

3. Do you feel that you can depend on any body in your neighbourhood when you need help?

   Definitely + 1 2 3 4 5 - Definitely not

4. Do you rely more on your relatives/ friends from other neighbourhoods than your neighbours for help? Yes ..... No ...... [✓]

5. Do you know the next door neighbours before you moved in? Yes ..... No ...... [✓]

   if yes, who are they? Relatives .... Friends .... Others, please specify ....

6. How many families do you know in the neighbourhood?

   None ... Less than 5 .... 5-10 .... 10-15 .... More ....

7. How many relatives do you have in this neighbouhood?

   None ... Less than 5 .... 5-10 .... 10-15 .... More ....

8. Does your wife work or stay at home?

   Work .... Stay at home ....

9. Does this neighbourhood give your wife enough segregation and privacy to walk?

   Enough + 1 2 3 4 5 - Not Enough

10. Do you agree that it is dangerous for your children to play outside the house in this neighbourhood?

    Agree + 1 2 3 4 5 -Disagree

11. Do you feel that the crime rate where you live is high or low?

    Low + 1 2 3 4 5 - High

12. Which crucial factors influenced you to choose to live here?

    Friends .... Relatives .... Neighbours ... Nearness to the workplace ... Financial ....

13. What kind of public facilities are provided in this nieghbourhood?

    Hospital .... School .... Shops/ Grocery ....

    Mosque .... Public spaces .... Public transport ....

14. What social privacy do you have due to courtyard in the building?

    High+ 1 2 3 4 5 -Low

15. Any comment you would like to add: ....
    ....
    ....
    ....

SECTION C: THERMAL ENVIRONMENT AND PERSONAL INFLUENCES

Environmental quality and satisfaction of the condition of the building, to assess your overall liking of the building in which you live. Please rate your building on each of the following scales, and indicate like this [/], where 3 is the middle position:

	Overall, do you like the ... (Strongly Dislike / DisLike / Neutral / Like / Strongly Like)	How important is this in your Building. (very Unimportant / Unimportant / Neutral / Important / very Important)
1. ... outward appearance of your building	1 2 3 4 5	1 2 3 4 5
2. ... the design of you building?	1 2 3 4 5	1 2 3 4 5
3. ... this climate in general?	1 2 3 4 5	1 2 3 4 5

Comments:

4. This part is to assess the a level of maintenance of your building, so;
- How often is your building maintenance? ....
- Who maintain it? ....
- When is it mainted? ....
- Is it easy to maintain? ....

5. Do you like the building in general? why? and what do you like most? ....
....
....
....

6. This part is assessment of your outdoor environment in general;

- Do you find the environment in general acceptable? (i.e. noises, social, aesthetic, scenery, etc.)
  Yes .... No .... [✓]
  if yes, why? ....
  ....
  if no, why? ....
  ....
- Any additional note; ....
  ....
  ....

SECTION D: ENVIRONMENTAL CONDITIONS IN WHOLE BUILDING

Zone One: Courtyard

In this zone the objective is to evaluate Environmental quality and of residents satisfaction of the condition of the courtyard; to assess your overall liking of the courtyard. Please rate your courtyard on each of the following scales, and indicate like this [/], where 3 is the middle position:

	Overall, do you like the ...	How important is this in your Building
	Strongly Dislike / DisLike / Neutral / Like / Strongly Like	very Unimportant / Unimportant / Neutral / Important / very Important
1. ... noise level	1 2 3 4 5	1 2 3 4 5
2. ... natural lighting (sunlight)	1 2 3 4 5	1 2 3 4 5
3. ... electric lighting (mechanical)	1 2 3 4 5	1 2 3 4 5

Comments:

4. ...natural ventilation	1 2 3 4 5	1 2 3 4 5
5. ...artificial ventilation	1 2 3 4 5	1 2 3 4 5
6. ...amount of air movement	1 2 3 4 5	1 2 3 4 5
7. ...courtyard temperature	1 2 3 4 5	1 2 3 4 5
8. ...humidity level in the courtyard	1 2 3 4 5	1 2 3 4 5

Comments:

9. ... shadow in the courtyard	1 2 3 4 5	1 2 3 4 5
10. ...corridor surrounding the courtyard	1 2 3 4 5	1 2 3 4 5
11. ...windows and doors opening into the courtyard	1 2 3 4 5	1 2 3 4 5

/ Cont. section D, zone one.

	Strongly Dislike	DisLike	Neutral	Like	Strongly Like	very Unimportant	Unimportant	Neutral	Important	very Important
12. ... windows opening to outside	1	2	3	4	5	1	2	3	4	5

Comments:

13. ... control you have over its temperature	1	2	3	4	5	1	2	3	4	5
14. ... control you have over ventilation	1	2	3	4	5	1	2	3	4	5
15. ... control you have over lighting	1	2	3	4	5	1	2	3	4	5

Comments:

16. Does your courtyard have a roof? Yes .... No .... [✓]
If not, tick the box that best describes the time of day the sunshine enters into it:

hardly ever	AM	PM	most of the day

17. Does your courtyard has fountains or pools? Yes .... No .... [✓]
If yes, please tick the box that best describes the amount it has been used:

not used	rarely	often	most of the day

18. Please tick the box that best describes how often you are too hot in the courtyard:

None	less than 5 days	5-10 days	10-20 days	20-30 days	more than 30 days	all

19. Please tick the box that best describes how often you are too cold in the courtyard:

None	less than 5 days	5-10 days	10-20 days	20-30 days	more than 30 days	all

SECTION D: ENVIRONMENTAL CONDITION IN THE WHOLE BUILDING

Zone Two: Rooms Surrounding the Courtyard

In this zone the objective is to evaluate Environmental quality and of residents satisfaction of the condition of rooms surrounding the courtyard; To assess your overall liking of visiting room and bedroom. Please rate your rooms on each of the following scales, and indicate like this [/], where 3 is the middle position:

NOTE: FROM 1 TO 11 DEALING WITH VISITING ROOM ONLY.

	Overall, do you like the ...	How important is this in your Building
	Strongly Dislike / DisLike / Neutral / Like / Strongly Like	very Unimportant / Unimportant / Neutral / Important / very Important
1. ... noise level	1 2 3 4 5	1 2 3 4 5
2. ... natural lighting (sunlight)	1 2 3 4 5	1 2 3 4 5
3. .. electric lighting (mechanical)	1 2 3 4 5	1 2 3 4 5
4. ...natural ventilation	1 2 3 4 5	1 2 3 4 5
5. ...artificial ventilation	1 2 3 4 5	1 2 3 4 5
6. ...amount of air movement	1 2 3 4 5	1 2 3 4 5
7. ... temperature	1 2 3 4 5	1 2 3 4 5
8. ...humidity level	1 2 3 4 5	1 2 3 4 5
9. Shadow level	1 2 3 4 5	1 2 3 4 5
10. ... windows opening to outside	1 2 3 4 5	1 2 3 4 5
11. ... door opening to outside	1 2 3 4 5	1 2 3 4 5

Comments:

/ Cont. Section D, zone two.

NOTE: FROM 12 TO 24 DEALING WITH BEDROOM ONLY

Please rate your room on each of the following scales, and indicate like this [/], where 3 is the middle position:

	Overall, do you like the ...					How important is this in your Building				
	Strongly Dislike	DisLike	Neutral	Like	Strongly Like	very Unimportant	Unimportant	Neutral	Important	very Important
12. ... noise level	1	2	3	4	5	1	2	3	4	5
13. ... natural lighting (sunlight)	1	2	3	4	5	1	2	3	4	5
14. .. electric lighting (mechanical)	1	2	3	4	5	1	2	3	4	5
15. ...natural ventilation	1	2	3	4	5	1	2	3	4	5
16. ...artificial ventilation	1	2	3	4	5	1	2	3	4	5
17. ...amount of air movement	1	2	3	4	5	1	2	3	4	5
18. ... temperature	1	2	3	4	5	1	2	3	4	5
19. ...humidity level	1	2	3	4	5	1	2	3	4	5
20. ... shadow level	1	2	3	4	5	1	2	3	4	5
21. ... windows opening to outside	1	2	3	4	5	1	2	3	4	5
22. ... door opening to outside	1	2	3	4	5	1	2	3	4	5

Comments:

23. Please tick the box that best describes how often you are too hot:

None	less than 5 days	5-10 days	10-20 days	20-30 days	more than 30 days	all

24. Please tick the box that best describes how often you are too cold:

None	less than 5 days	5-10 days	10-20 days	20-30 days	more than 30 days	all	

SECTION E:THERMAL COMFORT

Please answer the following questions concerned with your thermal comfort, and rate your building in Summer on each of the following scales, and indicate like this [/], where 3 is the middle position:

1. Please indicate the room which YOU occupy NOW on the box below.

....

2. In this room which you occupy, please indicate on the scales below how YOU feel NOW.

Very Uncomfortable	4	Very Dry	4	Very Sticky	4	Very Draughty	4
Uncomfortable	3	Dry	3	Sticky	3	Draughty	4
Slightly Uncomfortable	2	Slightly Dry	2	Slightly Sticky	2	Slightly Draughty	2
Comfortable	1	Not Dry	1	Not Sticky	1	Not Draughty	1

3. Please indicate on the scales below how YOU feel NOW.

hot	3
warm	2
slightly warm	1
neutral	0
slightly cool	-1
cool	-2
cold	-3

4. Please indicate on the scales below how YOU feel the air freshness NOW.

very stuffy	5
stuffy	4
neutral	3
fresh	2
very fresh	1

5. Please indicate how YOU would like to be NOW.

Warmer ..... No Change ..... Cooler ..... [✓]

6. Do YOU feel either cool or warm NOW anywhere on your body? Yes .... No .... [✓]

cool ... warm ....

if yes, where? Head ... Shoulders .... Trunk ... Arms ... Hands ....
Above Knee .... Below Knee .... Feet. ......

Is it uncomfortable? Yes ..... No ..... [✓]

7. Have YOU noticed any movement of air?
Yes .... No .... [✓]
if yes, where? Face/ Neck/ Hands/ Feet.
Is it uncomfortable? Yes ..... No ..... [✓]

8. Are YOU NOW satisfied with your thermal environment? Yes .... No .... [✓]
if Yes, why? ....
....
if No, why? ....
....

9. What do YOU feel GENERALLY about the design and construction of your building?

beautiful	1	2	3	4	5	ugly
relaxed	1	2	3	4	5	tense
colourful	1	2	3	4	5	dull

10. With reference to the design of your building please indicate on the thermal scales below how YOU feel GENERALLY.

	overall	courtyard	visiting room	bedrooms	kitchen	toilets
Very Uncomfortable	4	4	4	4	4	4
Uncomfortable	3	3	3	3	3	4
Slightly Uncomfortable	2	2	2	2	2	2
Comfortable	1	1	1	1	1	1

11. Please indicate on the draught scales below how YOU feel GENERALLY.

	overall	courtyard	visiting room	bedrooms	kitchen	toilets
Very Draughty	4	4	4	4	4	4
Draughty	3	3	3	3	3	4
Slightly Draughty	2	2	2	2	2	2
Not Draughty	1	1	1	1	1	1
Please tick the appropriate box (es) if it is uncomfortable	☐	☐	☐	☐	☐	☐

12. Please indicate on the dryness scales below how YOU feel GENERALLY.

	overall	courtyard	visiting room	bedrooms	kitchen	toilets
Very Sticky	4	4	4	4	4	4
Sticky		3	3	3	3	4
Slightly Sticky	2	2	2	2	2	2
Not Sticky	1	1	1	1	1	1
Please tick the appropriate box (es) if it is uncomfortable	☐	☐	☐	☐	☐	☐

/ Cont Section E

13. With reference to the design of your building please indicate on the scale below how YOU feel GENERALLY.

	overall	courtyard	visiting room	bedrooms	kitchen	toilets
hot	3	3	3	3	3	3
warm	2	2	2	2	2	2
slightly warm	1	1	1	1	1	1
neutral	0	0	0	0	0	0
slightly cool	-1	-1	-1	-1	-1	-1
cool	-2	-2	-2	-2	-2	-2
cold	-3	-3	-3	-3	-3	-3

14. Please indicate on the scale below how YOU feel the air freshness GENERALLY

	overall	courtyard	visiting room	bedrooms	kitchen	toilets
very stuffy	5	5	5	5	5	5
stuffy	4	4	4	4	4	4
neutral	3	3	3	3	3	3
fresh	2	2	2	2	2	2
very fresh	1	1	1	1	1	1

15. Please indicate how YOU would like to be GENERALLY

Warmer ..... No Change ..... Cooler ..... [✓]

16. Are YOU GENERALLY satisfied with your thermal environment? Yes .... No .... [✓]

if Yes, why? ....
....

if Yes, why? ....
....

17. Any Addition comments: ....
....
....

SECTION F: GENERAL FEELING AND PERSONAL WELL BEING.

The following questions ask for your general feelings about the building and your personal well-being,

1. Do you like to live in a building with a courtyard, or without? Yes .... No .... [✓]
   if Yes, why? ....
   if No, why? ....

2. Do you use air conditioning units in summer? Yes .... No .... [✓]
   if Yes, why? ....
   if No, why? ....

3. Generally, between 2:00 PM and 5:00 PM in summer do you usually feel relaxed and sleep?
   Yes .... No .... [✓]
   if Yes, why? ....
   if No, why? ....

4. When the outside temperature becomes very hot in summer, can you find a sufficient store or reserve of energy which you can call upon at times when you need it, to spur you on into action?
   Yes .... No .... [✓]
   if Yes, why? ....
   if No, why? ....

5. What are your feelings about the interior of your building? Like .... Dislike .... [✓]
   if Yes, why? ....
   if No, why? ....

6. Do you think that a traditional house is the right accommodation for you and your family?
   Yes .... No .... [✓]
   if Yes, why? ....
   if No, why? ....

7. Do you prefer to live in a traditional building more than to live in a modern building?
   Yes .... No .... [✓]
   if Yes, why? ....
   if No, why? ....

8. Do you prefer to live in a newly-built traditional design buildings with narrow shaded streets even if they are constructed using modern materials? Yes .... No .... [✓]
   if Yes, why? ....
   if No, why? ....

if your answer was yes in the previous question, could you please answer q.9.

9. Do you like the courtyard to be open or closed? and why?
   Open .... Closed ....
   Because;..
   ....
   ....

/ Cont. Section F

10. Where do you sleep in nights? [✓]
a) in a bedroom. [....]
b) in the courtyard. [....]
c) in the visiting room. [....]
d) on the roof of the building. [....]

11. Can you go outside your building at 2:00-5:00 pm. during summer?
Yes .... No .... [✓]
if Yes, why? ....
if No, why? ....

12. Do you enjoy the outdoor space? Yes .... No .... [✓]
if Yes, is it because:
a) there is no wind, sound, or dust; ....
b) it is a suitable temperature; ....
c) there is no humidity; ....
d) others?..

13. Would you find this an acceptable environment to live in?
....
....

14. What aspects of the new design of building do you think are better for the people in hot-dry climate regions?
....
....
....

15. Did you find this questionn-aire easy to answer? Yes .... No .... [✓]

16. Did the questionaire make you more aware of your building environment? Yes ... No .... [✓]

17. How might the questionaire be improved?
....
....

18. Please give any additional information or comments which you think are relevant to the assessment of your thermal environment.
....
....
....
....
....

Thank you very much for your time.

MASOUR ALI EALIWA, PhD Research Student
Department of Building Studies, School of the Built Environment
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QUESTIONNAIRE ONE: FOR RESIDENTS IN A MODERN BUILDING.
(AC)
This section is considering for Summer Season only.

Residential Survey

- Name of Project: ....
- Name of Interviewer: ....
- Date: ....
- Block Number ....
- Orientation: ....
- Name of respondent (husband or wife or others):..
- Location: .... City .... Village .... New town

SECTION A: BACKGROUND INFORMATION

1. What is the size of your household? .... Male .... Female
2. What ages are the people in the houses? Adults ....
   Children (under 18) ....
3. How long have you lived in this neighbourhood? .... Year/s .... Months
4. How long have you lived in this building? .... Year/s .... Months
5. Are you the owner or renter of this building? .... Owner .... Renter
6. Do you have another building (in the old form)? Yes ...... No [✓]
   If yes, do you still live in it? Yes .... No ....
   If no, why do you not live in it? ....
   ....
7. How many hours per day do you normally spend in the building? .... hour(s)
8. How many floors are in your building? 1 ...... 2 .... 3 .... More ....
9. How many bedrooms are in your house? 1 2 3 If more than 3 how many? ....
10. How many toilets are in your house? 1 2 3
11. Do you have in your building any mechanical ventilation? Yes ..... No ..... [✓]
    What is it? (i.e. disk fans, selling fans, air-conditioning) ....
    and where? (i.e. Bedroom, Kitchen, etc.) ....
    any comments; ....

SECTION B : SOCIAL INTERACTION

Please rate your building on each of the following scales, when it is required, where 3 is the middle position:

1. How close do you think you are with your next door neighbours?

   Too close+ 1 2 3 4 5 -Too distant

2. How often do you talk to the persons next door?

   Every day+ 1 2 3 4 5 -Never

3. Do you feel that you can depend on any body in your neighbourhood when you need help?

   Definitely + 1 2 3 4 5 - Definitely not

4. Do you rely more on your relatives/ friends from other neighbourhoods than your neighbours for help? Yes ..... No ...... [✓]

5. Do you know the next door neighbours before you moved in? Yes ..... No ...... [✓]

   if yes, who are they? Relatives .... Friends .... Others, please specify ....

6. How many families do you know in the neighbourhood?

   None ... Less than 5 .... 5-10 .... 10-15 .... More ....

7. How many relatives do you have in this neighbouhood?

   None ... Less than 5 .... 5-10 .... 10-15 .... More ....

8. Does your wife work or stay at home?

   Work .... Stay at home ....

9. Does this neighbourhood give your wife enough segregation and privacy to walk?

   Enough + 1 2 3 4 5 - Not Enough

10. Do you agree that it is dangerous for your children to play outside the house in this neighbourhood?

    Agree + 1 2 3 4 5 -Disagree

11. Do you feel that the crime rate where you live is high or low?

    Low + 1 2 3 4 5 - High

12. Which crucial factors influenced you to choose to live here?

    Friends .... Relatives .... Neighbours ... Nearness to the workplace ... Financial ....

13. What kind of public facilities are provided in this nieghbourhood?

    Hospital .... School .... Shops/ Grocery ....
    Mosque .... Public spaces .... Public transport ....

14. What social privacy do you have due to new design of the building?

    High+ 1 2 3 4 5 -Low

15. Any comment you would like to add: ....
    ....
    ....

SECTION C: THERMAL ENVIRONMENT AND PERSONAL INFLUENCES

Environmental quality and satisfaction of the condition of the building, to assess your overall liking of the building in which you live. Please rate your building on each of the following scales, and indicate like this [/], where 3 is the middle position:

	Overall, do you like the ...	How important is this in your Building.
	Strongly Dislike / DisLike / Neutral / Like / Strongly Like	very Unimportant / Unimportant / Neutral / Important / very Important
1. ... outward appearance of your building	1 2 3 4 5	1 2 3 4 5
2. ... the design of you building?	1 2 3 4 5	1 2 3 4 5
3. ... this climate in general?	1 2 3 4 5	1 2 3 4 5

Comments:

4. This part is to assess the a level of maintenance of your building, so;
- How often is your building maintenance? ....
- Who maintain it? ....
- When is it mainted? ....
- Is it easy to maintain? ....

5. Do you like the building in general? why? and what do you like most? ....
....
....
....

6. This part is assessment of your outdoor environment in general;

- Do you find the environment in general acceptable (i.e. noises, social, aesthetic, scenery, etc.)?
Yes .... No .... [✓]

if yes, why? ....
....

if no, why? ....
....

- Any additional note; ....
....
....

SECTION D: ENVIRONMENTAL CONDITION IN THE WHOLE BUILDING

Visiting room, Sitting room and Bedroom (One Zone Only)

In this zone the objective is to evaluate Environmental quality and of residents satisfaction of the condition of rooms within your modern building; to assess your overall liking of visiting room, sitting room and bedroom. Please rate your room on each of the following scales, and indicate like this [/], where 3 is the middle position:

NOTE: FROM 1 TO 11 DEALING WITH VISITING ROOM ONLY.

	Overall, do you like the ...	How important is this in your Building
	Strongly Dislike / DisLike / Neutral / Like / Strongly Like	very Unimportant / Unimportant / Neutral / Important / very Important
1. ... noise level	1 2 3 4 5	1 2 3 4 5
2. ... natural lighting (sunlight)	1 2 3 4 5	1 2 3 4 5
3. .. electric lighting (mechanical)	1 2 3 4 5	1 2 3 4 5
4. ...natural ventilation	1 2 3 4 5	1 2 3 4 5
5. ...artificial ventilation	1 2 3 4 5	1 2 3 4 5
6. ...amount of air movement	1 2 3 4 5	1 2 3 4 5
7. ... temperature	1 2 3 4 5	1 2 3 4 5
8. ...humidity level	1 2 3 4 5	1 2 3 4 5
9. Shadow level	1 2 3 4 5	1 2 3 4 5
10. ... windows opening to outside	1 2 3 4 5	1 2 3 4 5
11. ... door opening to outside	1 2 3 4 5	1 2 3 4 5

Comments:

/ Cont. Section D.

NOTE: FROM 12 TO 24 DEALING WITH BEDROOM ONLY

Please rate your room on each of the following scales, and indicate like this [/], where 3 is the middle position:

	Overall, do you like the ...					How important is this in your Building				
	Strongly Dislike	DisLike	Neutral	Like	Strongly Like	very Unimportant	Unimportant	Neutral	Important	very Important
12. ... noise level	1	2	3	4	5	1	2	3	4	5
13. ... natural lighting (sunlight)	1	2	3	4	5	1	2	3	4	5
14. .. electric lighting (mechanical)	1	2	3	4	5	1	2	3	4	5
15. ...natural ventilation	1	2	3	4	5	1	2	3	4	5
16. ...artificial ventilation	1	2	3	4	5	1	2	3	4	5
17. ...amount of air movement	1	2	3	4	5	1	2	3	4	5
18. ... temperature	1	2	3	4	5	1	2	3	4	5
19. ...humidity level	1	2	3	4	5	1	2	3	4	5
20. ... shadow level	1	2	3	4	5	1	2	3	4	5
21. ... windows opening to outside	1	2	3	4	5	1	2	3	4	5
22. ... door opening to outside	1	2	3	4	5	1	2	3	4	5

Comments:

23. Please tick the box that best describes how often you are too hot:

None	less than 5 days	5-10 days	10-20 days	20-30 days	more than 30 days	all

24. Please tick the box that best describes how often you are too cold:

None	less than 5 days	5-10 days	10-20 days	20-30 days	more than 30 days	all

/ Cont. Section D.

NOTE: FROM 25 TO 37 DEALING WITH SITTING ROOM ONLY

Please rate your room on each of the following scales, and indicate like this [/], where 3 is the middle position:

	Overall, do you like the ...	How important is this in your Building
	Strongly Dislike, DisLike, Neutral, Like, Strongly Like	very Unimportant, Unimportant, Neutral, Important, very Important
25. ... noise level	1 2 3 4 5	1 2 3 4 5
26. ... natural lighting (sunlight)	1 2 3 4 5	1 2 3 4 5
27. .. electric lighting (mechanical)	1 2 3 4 5	1 2 3 4 5
28. ...natural ventilation	1 2 3 4 5	1 2 3 4 5
29. ...artificial ventilation	1 2 3 4 5	1 2 3 4 5
30. ...amount of air movement	1 2 3 4 5	1 2 3 4 5
31. ... temperature	1 2 3 4 5	1 2 3 4 5
32. ...humidity level	1 2 3 4 5	1 2 3 4 5
33. ... shadow level	1 2 3 4 5	1 2 3 4 5
34. ... windows opening to outside	1 2 3 4 5	1 2 3 4 5
35. ... door opening to outside	1 2 3 4 5	1 2 3 4 5

Comments:

36. Please tick the box that best describes how often you are too hot:

None	less than 5 days	5-10 days	10-20 days	20-30 days	more than 30 days	all

37. Please tick the box that best describes how often you are too cold:

None	less than 5 days	5-10 days	10-20 days	20-30 days	more than 30 days	all

SECTION E:THERMAL COMFORT

Please answer the following questions concerned with your thermal comfort, and rate your building in Summer on each of the following scales, and indicate like this [/], where 3 is the middle position:

1. Please indicate the room which YOU occupy NOW on the box below.

....

2. In this room which you occupy, please indicate on the scales below how YOU feel NOW.

Very Uncomfortable	4	Very Dry	4	Very Sticky	4	Very Draughty	4
Uncomfortable	3	Dry	3	Sticky	3	Draughty	4
Slightly Uncomfortable	2	Slightly Dry	2	Slightly Sticky	2	Slightly Draughty	2
Comfortable	1	Not Dry	1	Not Sticky	1	Not Draughty	1

3. Please indicate on the scales below how YOU feel NOW.

hot	3
warm	2
slightly warm	1
neutral	0
slightly cool	-1
cool	-2
cold	-3

4. Please indicate on the scales below how YOU feel the air freshness NOW.

very stuffy	5
stuffy	4
neutral	3
fresh	2
very fresh	1

5. Please indicate how YOU would like to be NOW.

Warmer ..... No Change ..... Cooler ..... [✓]

6. Do YOU feel either cool or warm NOW anywhere on your body? Yes .... No .... [✓]

cool ... warm ....

if yes, where? Head ... Shoulders .... Trunk ... Arms ... Hands ....
Above Knee .... Below Knee .... Feet. ......

Is it uncomfortable? Yes ..... No ..... [✓]

7. Have YOU noticed any movement of air?
Yes .... No .... [✓]
if yes, where? Face/ Neck/ Hands/ Feet.
Is it uncomfortable? Yes ..... No ..... [✓]

8. Are YOU NOW satisfied with your thermal environment? Yes .... No .... [✓]
if Yes, why? ....
....
if No, why? ....
....

/ Cont Section E

---

9. What do YOU feel GENERALLY about the design and construction of your building?

beautiful	1	2	3	4	5	ugly
relaxed	1	2	3	4	5	tense
colourful	1	2	3	4	5	dull

10. With reference to the design of your building please indicate on the thermal scales below how YOU feel GENERALLY.

	overall	courtyard	visiting room	bedrooms	kitchen	toilets
Very Uncomfortable	4	4	4	4	4	4
Uncomfortable	3	3	3	3	3	4
Slightly Uncomfortable	2	2	2	2	2	2
Comfortable	1	1	1	1	1	1

11. Please indicate on the draught scales below how YOU feel GENERALLY.

	overall	courtyard	visiting room	bedrooms	kitchen	toilets
Very Draughty	4	4	4	4	4	4
Draughty	3	3	3	3	3	4
Slightly Draughty	2	2	2	2	2	2
Not Draughty	1	1	1	1	1	1
Please tick the appropriate box (es) if it is uncomfortable	☐	☐	☐	☐	☐	☐

12. Please indicate on the dryness scales below how YOU feel GENERALLY.

	overall	courtyard	visiting room	bedrooms	kitchen	toilets
Very Sticky	4	4	4	4	4	4
Sticky		3	3	3	3	4
Slightly Sticky	2	2	2	2	2	2
Not Sticky	1	1	1	1	1	1
Please tick the appropriate box (es) if it is uncomfortable	☐	☐	☐	☐	☐	☐

/ Cont Section E

13. With reference to the design of your building please indicate on the scale below how YOU feel GENERALLY.

	overall	courtyard	visiting room	bedrooms	kitchen	toilets
hot	3	3	3	3	3	3
warm	2	2	2	2	2	2
slightly warm	1	1	1	1	1	1
neutral	0	0	0	0	0	0
slightly cool	-1	-1	-1	-1	-1	-1
cool	-2	-2	-2	-2	-2	-2
cold	-3	-3	-3	-3	-3	-3

14. Please indicate on the scale below how YOU feel the air freshness GENERALLY

	overall	courtyard	visiting room	bedrooms	kitchen	toilets
very stuffy	5	5	5	5	5	5
stuffy	4	4	4	4	4	4
neutral	3	3	3	3	3	3
fresh	2	2	2	2	2	2
very fresh	1	1	1	1	1	1

15. Please indicate how YOU would like to be GENERALLY

Warmer ..... No Change ..... Cooler ..... [✓]

16. Are YOU GENERALLY satisfied with your thermal environment? Yes .... No .... [✓]

if Yes, why? ....
....

if Yes, why? ....
....

17. Any Addition comments: ....
....
....

SECTION F: GENERAL FEELING AND PERSONAL WELL BEING.

The following questions ask for your general feelings about the building and your personal well-being,

1. Do you like to live in this building withoutany changes? Yes .... No .... [✓]
   if Yes, why? ....
   if No, why? ....

2. Do you use air conditioning units in summer? Yes .... No .... [✓]
   if Yes, why? ....
   if No, why? ....

3. Generally, between 2:00 PM and 5:00 PM in summer do you usually feel relaxed and sleep?
   Yes .... No .... [✓]
   if Yes, why? ....
   if No, why? ....

4. When the outside temperature becomes very hot in summer, can you find a sufficient store or reserve of energy which you can call upon at times when you need it, to spur you on into action?
   Yes .... No .... [✓]
   if Yes, why? ....
   if No, why? ....

5. What are your feelings about the interior of your building? Like .... Dislike .... [✓]
   if Yes, why? ....
   if No, why? ....

6. Do you think that a traditional house is the right accommodation for you and your family?
   Yes .... No .... [✓]
   if Yes, why? ....
   if No, why? ....

7. Do you prefer to live in a modern building more than to live in a traditional building?
   Yes .... No .... [✓]
   if Yes, why? ....
   if No, why? ....

8. Do you prefer to live in a newly-built traditional design buildings with narrow shaded streets even if they are constructed using modern materials? Yes .... No .... [✓]
   if Yes, why? ....
   if No, why? ....

If your answer was yes in the previous question, could you please answer q.9.

9. Do you like the courtyard to be open or closed? and why?
   Open .... Closed ....
   Because;..
   ....
   ....

/ Cont. Section F

10. Where do you sleep on summer nights? [✓]
a) in a bedroom. [....]
b) in the sitting room. [....]
c) in the visiting room. [....]
d) on the roof of the building. [....]

11. Can you go outside your building at any time during summer?
Yes .... No .... [✓]
if Yes, why? ....
if No, why? ....

12. Do you enjoy the outdoor space? Yes .... No .... [✓]
if Yes, is it because
a) there is no wind, sound, or dust; ....
b) it is a suitable temperature; ....
c) there is no humidity; ....
d) others? ....

13. Would you find this an acceptable environment to live in?
....
....

14. What aspects of the new design of building do you think are better for the people in hot-dry climate regions?
....
....
....

15. Did you find this questionnaire easy to answer? Yes .... No ...

16. Did the questionaire make you more aware of your building environment? Yeas ... No ....

17. How might the questionaire be improved?
....
....

18. Please give any additional information or comments which you think are relevant to the assessment of your thermal environment.
....
....
....

Thank you very much for your time.

MASOUR ALI EALIWA, Ph.D. Research Student
Department of Building Studies
School of the Built Environment
De Montfort University. The Gateway, Leicester, LE1 9BH, England, UK.

APPENDIX B:

Questionnaire, health and general form in Arabic

Questionnaire in Arabic: Sample of Old Building

—

نموذج متعلق بالناحية الصحية و تعهد من الشخص المراد عمل الدراسة معه

يرجى قراءة البيانات التالية بعناية

الشخص الذي يمكن اعتباره معفي من مثل هذا الاختبار في حالة:

- عمره تحت 4 سنوات.
- لديه سكر او مرض معدي.
- لديه حمى.
- لديه تخلف عقلي.
- لديه مرض عصبي.
- لديه مرض نفسي.
- أصم او قام باجراء عملية جراحية بالعين.
- لديه انهيار او اضطرابات بسبب مرض عصبي.
- لديه سعال او سقاما او يعاني من وجود دم في البراز.
- لديه ضغط الدم او مرض القلب.
- لديه الام دورية، او متقطعة، او يعاني من تنمل في الأطراف.
- قام باجراء او عملية جراحية خلال 6 اشهر ماضية.
- مرض حساسية جلدية، هبوط او ارتفاع في درجة الحرارة، ضربة شمس.
- لديه تقيؤ او مشاكل في الجهاز التنفسي.
- يعاني من الربو (الأزمة) او اي مرض صدري.
- لديه مشاكل تخثر الدم.

الاسم: الطيب محمد الحبيب طنيبة

العمر: ....1971........

هل انت بصحة جيدة؟ نعم ✓ لا ..... [✓]

لو كانت الاجابة بلا، هل لك ان توضح الأسباب. ....

....

هل سبق وان عانيت من مرض او اصابات؟ نعم .. لا ✓ [✓]

لو كانت الاجابة نعم، هل لك ان تشرح ذلك. ....

....

هل سبق لك ان اجريت المعاينة الصحية؟ نعم ..... لا ✓ [✓]

لو كانت الاجابة بنعم، هل لك ان تشرح ذلك: ....

....

التعهد

اتعهد انا .الطيب محمد طنيبة. بانني لا ارى مانع من اجراء هذا الاختبار عليّ. والمتعلق بدراسة و تسجيل المستويات الحرارية لراحة الساكنين داخل المسكن، وذلك بتاريخ 16/8/1997م.
ان اجابتي على الأسئلة السابقة وايضا امثلة الاستبيانات صحيحة و ذلك حسب ماعندي من معلومات واعلم بانه سوف تساعد في استكمال هذا العمل بالصورة المطلوبة. كذلك فاني اقر بانه قد تم شرح كل ماهو مطلوب مني و فهم جميع الاسئلة. اضافة الى ذلك فانه قد تم شرح وتفهيمي بانه يمكني الانسحاب في اي وقت اشاء و يمكنني ان اطلب تبديل الاختبار مرة اخرى. ايضا اتعهد بان التزم بالمحافظة على قواعد المحل الاختباري والمحافظة على سلامة الاجهزة المستعملة للقياسات اللازمة. وبناءا على ما سبق فاني اتعهد بذلك.

توقيع الشخص الخاضع للاختبار: .... توقيع الشخص القائم بالاختبار: ....

التاريخ: 16/8/1997م التاريخ: ..../..../1997م

نموذج متعلق بالملابس التي ترتديها

أرجو منك مشكورا تعبئة النموذج المعد لغرض معرفة نوع الملابس التي ترتديها عادة حسب الإمكانية والمعلومات التي لديك وإن كانت هناك أية إيضاحات ترغبها أو أية استفسارات فأرجو عدم التردد في السؤال عنها.

نوع المبنى: مبنى به هواء ...✓ مبنى حديث ...... [√]

الفصل: صيف ...✓ شتاء ...... التاريخ 16/8/1997.

الاسم: الطيب محمد المجدوب طبيبه ....

الجنس: ذكر ✓ أنثى ...... [√]

تاريخ الميلاد: 26/1/1971

الطول: 172

الوزن: 68 كلغم

الملابس المستعملة:

أرجو التكرم بكتابة أو تحديد نوع الملابس التي عادة ترتدونها في مثل هذا الجو.

غطاء الرأس (للنساء) أو الطاقية (للرجال): المعملة العربية ....

الملابس الخارجية أو القميص: الجبة (القشابة) ....

....

الجوارب: ....

سروال (تحت القميص): ....

الجزء العلوي من الحذاء: جلد مغلق بالكامل ....

الجزء السفلي من الحذاء: جلد صناعي ....

أية إضافات أخرى: ....

في العادة يلبسون قميص وسروال (البدلة العربية) ...

مع البرد والشال حيث أنه في الفرح يلبسونه بالشال المتعارف ...

عليه باسم (القدو) ...

الاستبيان الأول: خاص بسكان مبنى ذو فناء - 97/08/10.

الاستبيان الأول : خاص بسكان مبنى ذو فناء

هذا الجزء أعتبر على انه خاص بفصل الشتاء فقط

تقيم معيشي

اسم المشروع: ....
اسم جاري المقابلة : ....
التاريخ : ....
رقم القطعة : ....
الاتجاه : ....
اسم المقيم أو الساكن (الرجل أو الزوجة أو شخص اخر) : الطيب محمد الطيب ....
المكان : المدينة القديمة مدينة : غدامس ..... قرية: .... مدينة جديدة ....

قسم أ : معلومات عامة

1- ما عدد افراد أسرتك؟ 9 ذكور: ...7... اناث: ...2...
2- ما أعمار أفراد أسرتك ؟ كبار .29. ..31.. ..30...
5 6 8 10 صغار (أقل من 18 سنة) 12 ... 11
3- منذ متى سكنت في هذا الحي؟ سنوات .... أشهر ....
4- منذ متى سكنت في هذا المبنى؟ سنوات .... أشهر ....
5- هل أنت مالك أو مؤجر لهذا المبنى؟ مالك ...✓... مؤجر ....
6- هل لديك مبنى أخر (مبنى حديث) ؟ نعم ..✓.. لا ...... [√]
اذا نعم، هل مازلت تسكنه ؟ نعم ..✓.. لا ......
اذا لا، فلماذا لاتسكنه ؟ ....
....
7- كم ساعة في اليوم عادة ما تبقى داخل المبنى ؟ .... ساعة
8- كم عدد أدوار المبنى؟ 1 ..... 2 ...... 3 ..✓.. أو أكثر ....
9- كم عدد غرف النوم بالمبنى؟ 1 ..... 2 ..✓.. 3 ...... اذا أكثر من ذلك فكم العدد ؟....
10- كم عدد الحمامات بالمبنى؟ 1 ..✓.. 2 ...... 3 ......
11- هل لديك أية أجهزة ميكانيكية للتهوئة ؟ نعم ..... لا ..✓.. [√]
ما هي؟ (مثلا : مروحة مكتبية ,مروحة هوائية بالسقف , أو مكيف هواء) ....
وأين؟ (مثلا : بغرفة النوم , بالمطبخ والخ) ....
أية ملاحظات أخرى ؟ بالنسبة لغرف النوم غير ثابتة حيث أن موضع النوم يكون على السطح عادة.
....
....

الاستبيان الاول: حي بسكان مسي دو فساء - 97/08/10.

قسم ب: التفاعل الأجتماعي

أرجو التكرم باختيار المعدل المناسب الخاص بك على حسب المقياس الموضح لك، عندما يطلب منك ذلك، علما بأن 3 هو متوسط المقياس. -

1- كم تبعد المسافة بينك و بين اقرب جار لك بالحي؟
قريب جداً 1+ 2 3 4 5- بعيد جداً

2- كم مرة تتحدث و تلتقي بجارك؟
كل يوم 1+ 2 3 4 5- ولا مرة

3- هل تعتقد بانه يمكنك ان تعتمد على اي شخص بالحي الذي تسكنه عندما تحتاج لمساعدة؟
بكل تاكيد 1+ 2 3 4 5- لا يمكن ابداً

4- هل تعتمد اكثر عى اقاربك أم على اصدقائك بالاحياء الأخرى عندما تحتاج لمساعدة؟
نعم ..... لا ✓ [✓]

5- هل تعرف جيرانك قبل ان تنتقل لهذا المبنى؟ نعم ..... لا ..... [✓]
اذا نعم، لمن هم؟ اقارب ..... اصدقاء ..... آخرين، ارجو التوضيح .....

6- كم اسرة تعرف من الجيران حول المبنى الذي تسكنه؟
لاأحد .... اقل من 5 ..... 5 - 10 ..... 10-15 ..... اكثر ✓ (كلهم)

7- كم من الاقارب تعرف من هؤلاء الجيران؟ لاأحد ... اقل من 5 ... 5 - 10 ... 10-15 ..... اكثر ✓ (كلهم)

8- هل زوجتك تشتغل ام هي ربة بيت؟ تشتغل ..... ربة بيت ✓

9- هل سكان هذا الحي يمنحون أو يوفرون لزوجتك الحرية و الخصوصية المطلوبة التي تحتاجها للتنقل أو السير؟ حرية كافية 1+ 2 3 4 5- حرية غير كافية

10- هل تعتقد بانه توجد خطورة على اطفالك للعب خارج المبنى في هذا الحي؟
اوافق تماما 1+ 2 3 4 5- لا اوافق

11- هل تعتقد بان نسبة الجريمة في هذا الحي عالية أم منخفضة؟
عالية 1+ 2 3 4 5- منخفضة

12- ما هي اهم المسببات التي جعلتك تختار ان تسكن في هذا الحي؟
الاصدقاء ..... الاقارب ✓ (باستثناء الجيران) ..... القرب من مكان العمل .... اقتصاديا .....
الاصدقاء ..... الاقارب ..... الجيران ..... القرب من مكان العمل .... اقتصاديا .....

13- ما هي الخدمات المتوفرة للسكان بهذا الحي؟
مستشفى/ مستوصف ..... مدرسة ✓ محلات تجارية ✓
مكان عام ✓ جامع ✓ مواصلات عامة .....

14- ما مدى الخصوصية الاجتماعية المتوفرة لك ولاسرتك فيما لو اخذنا بعين الاعتبار الفناء؟
عالية 1+ 2 3 4 5- منخفضة

15- اية ملاحظات اخرى تريد اضافتها: ....
....
....

الاستبيان الاول: خاص بسكان مبنى ذو فناء - 97/08/10.

قسم ت: الحرارة البيئية والانطباعات الخاصة

ان البيئة البيئية والحالة المرضية والملائمة داخل المبنى لتعكس انطباع يحدد مدى ارتياحك له. لهذا ارجو منك التكرم باختيار المعدل المناسب للمبنى الخاص بك على حسب المقياس الموضح. على ان تختار [/]، علما بان 3 هو متوسط المقياس.

عموما، هل تحب او ترغب بال...

	راغب و بشدة	راغب	محايد/متعادل	غير راغب	غير راغب اطلاقا
	5	4	3	2	1
		/			
1- ... المنظر الخارجي		/			
2- ... تصميم المبنى		/			
3- ... الجو بصفة عامة	/				

كم هو مهم للمبنى الذى تقطنه

	مهم جدا	مهم	محايد/متعادل	غير مهم	غير مهم اطلاقا
	5	4	3	2	1
1- ... المنظر الخارجي				/	
2- ... تصميم المبنى	/				
3- ... الجو بصفة عامة	/				

ملاحظات/تعليقات: الامطار نادرة... ولكن نسبيه .. مشكلة لان كانت غزيرة. حيث أنها تتجمع على السطح... ويتم غرفها بشكل جماعي ... كما حدث في [illegible] قبل السبعينات ...

4- هذا الجزء لتقييم او تحديد مستوى او معدل ترميم المبنى، لذلك:

- كم مرة قمت بترميم مسكنك؟ ... الترميم على الحيشة .. جديد ... حوالي ... 4 - 5 مرات
- من قام بترميمه؟ ... [illegible] بالكامل ...
- هل كان ترميمه سهلا؟ ... [illegible] ...

5- هل انت مرتاح للمبنى ككل؟ ولماذا؟ وما هو الذى اعجبك به اكثر؟ .. نعم ...
[illegible] ...
[illegible] ...

...

6- هذا السؤال متعلقا بتحديد او تقييم البيئة الخارجية المحيطة بك بصورة عامة:

- هل وجدت ان البيئة الخارجية المحيطة بك مناسبة للعيش (من حيث الضوضاء، المشهد الجملي او الزخرفي، الحياة الاجتماعية، الخ) نعم ... لا ... [/]

اذا كانت الاجابة بنعم، فلماذا؟ .. لأن الضوضاء تعتبر طبيعية وغير صناعية .. المصحوبة بتوابع [illegible] الجو ...

...

اذا كانت الاجابة بلا، فلماذا ...

...

...

- اية اضافات اخرى؟ ...

...

...

/الاســتـبـيـان الاول: خـاص بـسـكان مـبـنـى ذو فـنـاء - 97/08/10.

قســم ث: الجـو المعيشـي داخـل المبنـى ككـل

المنـطـقـة الاولـى: الـفـنـاء

ان الغـايـة المـرجـوة من دراسـة هـذه المنطقة هي تحـليـل تقيمـة او الحـالة البيئيـة والوصـول الى اقصـى الغايات للسكان وذلك باستعمـالهم الفناء داخل المبنى حتى يتم تقييمه عمومـا. لهذا ارجو التكرم باختيـار المعدل الدال او المناسب لتقييم ذلك الفناء بكتابة [/] حسب ما يشير اليه المقياس المعد لذلك, حيث ان 3 هو متوسط ذلك المقياس.

عموما, هل تحب او ترغب بال...   كم هو مهم للمبنى لدى تقطنه؟

	ارغب و بشدة 5	ارغب 4	محايد/ متعادل 3	غير راغب 2	غير راغب اطلاقا 1	مهم جدا 5	مهم 4	محايد/ متعادل 3	غير مهم 2	غير مهم اطلاقا 1
1- ... مستوى الضجيج			/				/			
2- ... الاضاءة الطبيعية	/					/				
3- الاضاءة الغير طبيعية			/					/		

ملاحظات/ تعليقات: ....
....

	5	4	3	2	1	5	4	3	2	1
4-... تهوية طبيعية		/				/				
5-... تهوية صناعية					/				/	
6-.. كمية الهواء المتحرك			/				/			
7 .درجة حرارة الفناء	/					/				
8 . مستوى الرطوبة للفناء			/					/		

ملاحظات/ تعليقات: ... الفناء يتميز به فتحة من السقف وتفتح هذه الفتحة حوالي الساعة (11 او 10) صباحا الى الساعة (5 او 6) مساء وبعدها تقفل الى صباح اليوم التالي وهكذا ....
والتكييف صحيح صيفا ....

/الاستبيان الاول: حامي سكان مسي ذو فناء - 97/08/10.

/ يتبع قسم ث

9-... مستوى الظل داخل الفناء	5 4 3 2 1	5 4 3 2 1
10-...الطرقات و الاقواس حول الفناء	5 4 3 2 1	5 4 3 2 1
11-... الابواب و النوافذ المطلة على الفناء	5 4 3 2 1	5 4 3 2 1
12-... الابواب و النوافذ المطلة على الخارج	5 4 3 2 1	5 4 3 2 1

ملاحظات/تعليقات: ..لا يوجد أبواب ونوافذ مطلة على الخارج في الفناء.........
....

13-...القدرة على التحكم في درجة حرارة الفناء	5 4 3 2 1	5 4 3 2 1
14-. القدرة على التحكم في كمية الهواء بالفناء	5 4 3 2 1	5 4 3 2 1
15-...القدرة على التحكم في كمية الاضاءة بالفناء	5 4 3 2 1	5 4 3 2 1

ملاحظات/تعليقات: ....
....

16. هل الفناء الموجد بالمبنى له سقف (مغلق)؟ نعم .... لا [✓]
اذا لا, ارجو اختيار احد المربعات التي تشير او تعبر عن وقت دخول اشاعة الشمس بالفناء:

بصعوبة جداً	في الصباح	في المساء	في معظم اليوم

17. هل يوجد بالفناء نافورة أو حوض ماء؟ نعم .. لا [✓]
اذا نعم, ارجو اختيار احد المربعات التي تشير او تعبر عن عدد مرات استعمالك لها:

لا تستعمل	قليلا	غالبا	في معظم اليوم

18. ارجو اختيار احد المربعات التي تعبر عن مدى احساسك بالبرودة داخل الفناء في هذا الفصل:

ولا مرة	اقل من 5 ايام	5-10 ايام	10-20 يوما	20-30 يوما	اكثر من 30	كل الفصل

19. ارجو اختيار احد المربعات التي تعبر عن مدى احساسك بالحرارة داخل الفناء في هذا الفصل:

ولا مرة	اقل من 5 ايام	5-10 ايام	10-20 يوما	20-30 يوما	اكثر من 30	كل الفصل

الاستبيان الاول: عماص سكني مبني دو ساء - 97/08/10.

قسم ث: الجو المعيشي داخل المبنى ككل

المنطقة الثانية: الغرف المحيطة بالفناء

ان الغاية المرجوة من دراسة هذه المنطقة هي تحليل القيمة او الحالة البيئية والوصول الى اقصى الغايات للسكان وذلك بإستعمالهم الغرف المحيطة بذلك الفناء. لهذا ارجو التكرم بإختيار المعدل الدال او المناسب لتقييم تلك الغرفة بكتابة [✓] حسب ما يشير اليه المقياس المعد لذلك, حيث ان 3 هو متوسط ذلك المقياس.

<u>ملاحظة</u>: الاسئلة من 1 الى 11 متعلقة بحجرة الضيافة فقط

	عمومًا, هل تحب او ترغب بال...					كم هو مهم للمبنى الذى تقطنه				
	غير راغب اطلاقا	غير راغب	محايد/متعادل	ارغب	ارغب و بشدة	غير مهم اطلاقا	غير مهم	محايد/متعادل	مهم	مهم جدا
	1	2	3	4	5	1	2	3	4	5
1- ... مستوى الضجيج										
2- .. الاضاءة الطبيعية										
3- .. الاضاءة الغير طبيعية										
4- .. تهوية طبيعية										
5-... تهوية صناعية										
6-... كمية الهواء المتحرك										
7...درجة حرارة الفناء										
8... مستوى الرطوبة للفناء										
9-... مستوى الظل داخل الفناء										
10-. الابواب و النوافذ المطلة على الفناء										
11-... الابواب و النوافذ المطلة على الخارج										

ملاحظات/ تعليقات: ....
....

الاستبيان الاول: حامي سكان مبني ذو فناء - 97/08/10.

/ يتبع قسم ث. المنطقة الثانية

ملاحظة: الاسئلة من 12 الى 24 متعلقة بحجرة النوم فقط
ارجو التكرم باختيار المعدل الدال او المناسب لتقييم تلك الغرفة بكتابة [/] حسب ما يشير اليه المقياس المعد لذلك. حيث ان 3 هو متوسط ذلك المقياس.

	عموما، هل تحب او ترغب بال...					كم هو مهم للمبنى الذي تقطنه				
	غير راغب اطلاقاً	غير راغب	محايد/متعادل	ارغب	ارغب و بشدة	غير مهم اطلاقاً	غير مهم	محايد/متعادل	مهم	مهم جداً
	1	2	3	4	5	1	2	3	4	5
12- .. مستوى الضجيج			/					/		
13- ... الاضاءة الطبيعية					/					/
14- الاضاءة الغير طبيعية		/						/		
15-... تهوية طبيعية				/					/	
16-... تهوية صناعية	/					/				
17-... كمية الهواء المتحرك		/					/			
18-...درجة حرارة الفناء					/					/
19-... مستوى الرطوبة للفناء			/					/		
20-... مستوى الظل داخل الفناء	/					/				
21-... الابواب و النوافذ المطلة على الفناء			/						/	
22-... الابواب و النوافذ المطلة على الخارج			/					/		

ملاحظات/ تعليقات: [illegible]

23- ارجو اختيار احد المربعات التي تعبر عن مدى احساسك بالبرودة داخل الفناء في هذا الفصل:

ولا مرة	اقل من 5 ايام	5-10 ايام	10-20 يوما	20-30 يوما	اكثر من 30	كل الفصل

24- ارجو اختيار احد المربعات التي تعبر عن مدى احساسك بالحرارة داخل الفناء في هذا الفصل:

ولا مرة	اقل من 5 ايام	5-10 ايام	10-20 يوما	20-30 يوما	اكثر من 30	كل الفصل

الاستبيان الاول: خاص بسكان مبنى ذو فدا . 15/08/97م.

قسم ج: الجو او المعدل الحراري المناسب

ارجو التكرم بالاجابة على الاسئلة التالية والمتعلقة بتقييم الجو الحراري المناسب وذلك باختيارك المعدل الدال او المناسب لتقييم المبنى ككل حسب مايشير اليه المقياس او المعيار المعد لذلك بكتابة [/], حيث ان 3 هو متوسط ذلك المقياس.

1- ارجو ان تشير او تبين نوع الحجرة التى انت بها الان فى المربع التالى:

[الفصل ..6..........]

2- فى هذه الحجرة التى انت بها الان,ارجو ان تبين على المقياس التالى كيف تشعر انت الان!

غير مرتاح اطلاقا	4	جاف جدا	4	رطوبة شديدة	4	تيار هوائى شديد	4
غير مرتاح	3	جاف	3 /	رطوبة	3	تيار هوائى	3
مرتاح قليلا	2	جاف قليلا	2	رطوبة قليلة	2	تيار هوائى قليل	2
مرتاح جدا	1 /	غير جاف	1	لا توجد رطوبة	1 /	لا يوجد تيار هوائى	1 /

3- ارجو ان تبين على المقياس التالى كيف تشعر انت الان!

حار	3
دافئ	2
دافئ قليلا	1
محايد/ متعادل	0 /
بارد قليلا	1-
بارد باعتدال	2-
بارد جدا	3-

4- ارجو ان تبين على المقياس التالى كيف تشعر بنسمة الهواء انت الان!

هواء ملوث كثير	5
هواء ملوث	4
محايد/ متعادل	3
هواء نقى	2 /
هواء نقى جدا	1

5- ارجو ان تبين على المقياس التالى كيف تريد ان تكون انت الان!

ادفاء ..... لا تغيير ../.. ابرد .....

6- هل تشعر انت الان سواء ببرودة او حرارة فى اى جزء من جسمك؟

نعم ../. لا ..... [√] بارد ..... دافئ ./..

اذا اجابتك بنعم, فأين؟ الرأس ./. الكتفين ./. البدن ..... الذراعين ...

فوق الركبة . ... تحت الركبة ..... القدمين ./.

هل شعورك هذا غير مريح لك؟ نعم ./.. لا ..... [√]

7- هل لاحظت اية حركة للهواء؟ نعم ..... لا ../. [√]

اذا نعم, فأين؟ بالوجه ..... بالرقبة ..... باليدين ..... بالقدمين .....

هل شعورك هذا غير مريح لك؟ نعم ..... لا ..... [√]

8- هل انت الان مرتاح مع الجو البيئي المحيط بك بالحجرة؟ نعم ./.. لا . ... [√]

اذا نعم, فلماذا؟ ..لا..يوجد..ا..زعاج.../ د/ لان الجو عادى...........................

....

اذا لا, فلماذا؟ ....

....

لاسـبـيـانـات الـثـانـي: حـامي بـمـسـكان مـسـي دو فـنـاء - 97/08/10.

/ يتبع قسم ج.

13- بالاشارة الى التصميم المنفذ عليه المبنى ارجو ان تبين على المقياس التالى كيف تشعر انت عامة.

	بكل المبنى	بالفناء	بحجرة الضيافة	بحجرة النوم	بالمطبخ	بالحمام
حار	3	3	3	3 ✓	3 ✓	3
دافئ	2	2	2	2	2	2
دافئ قليلا	1	1	1 ✓	1	1	1
محايد/ متعادل	0 ✓	0 ✓	0	0	0	0 ✓
بارد قليلا	-1	-1	-1	-1	-1	-1
بارد باعتدال	-2	-2	-2	-2	-2	-2
بارد جدا	-3	-3	-3	-3	-3	-3

14- ارجو ان تبين على مقياس نسبة الهواء التالى والذى يوضح كيفية شعورك انت عامة.

	بكل المبنى	بالفناء	بحجرة الضيافة	بحجرة النوم	بالمطبخ	بالحمام
هواء ملوث كثير	5	5	5	5	5	3
هواء ملوث	4	4	4	4	4	2
محايد/ متعادل	3	3	3	3	3 ✓	1 ✓
هواء نقى	2 ✓	2 ✓	2 ✓	2 ✓	2	0
هواء نقى جدا	1	1	1	1	1	-1

15- ارجو ان تبين كيف تحب ان تكون انت عامة؛

ادفاء ..... لا تغيير ..... ابرد ..✓.

16- هل انت عامة مرتاح مع الجو البيىء المحيط بك بالحجرة؟ نعم ✓. لا ..... [√]

اذا نعم، فلماذا؟ ..نظراً بأنه الجو عامة طيب وعدم وجود أي سبب للإزعاج كالضوضاء وغيرها.....

اذا لا، فلماذا؟ ....

....

17- اية اضافات/ تعليقات؛ ....

....

....

....

/الامـــــــــــــــان الاول: خـاص بـسـكان مـبـنـى ذو فـنـاء– 97/08/10.

/ يتبـع قسـم ج.

13- بالاشـارة الى التصميم المنفذ عليه المبنى ارجو ان تبين على المقياس التالى كيف تشعر انت عامة.

	بكل المبنى	بالفناء	بحجة الضيافة	بحجرة النوم	بالمطبخ	بالحمام
حـار	3	3	3	3	3 ✓	3
دافـى	2 ✓	2	2	2 ✓	2	2 ✓
دافى قليلا	1 ✓	1 ✓	1	1	1	1
محايد/ متعادل	0	0	0	0	0	0
بارد قليلا	1-	1-	1-	1-	1-	1-
بارد باعتدال	2-	2-	2-	2-	2-	2-
بارد جدا	3-	3-	3-	3-	3-	3-

14- ارجو ان تبين على مقياس نسبة الهواء التالى والذى يوضح كيفية شعورك انت عامة.

	بكل المبنى	بالفناء	بحجة الضيافة	بحجرة النوم	بالمطبخ	بالحمام
هواء ملوث كثير	5	5	5	5	5	3
هـواء ملوث	4	4	4	4	4	2
محايد/ متعادل	3	3	3	3	3	1 ✓
هـواء نقـى	2 ✓	2 ✓	2	2 ✓	2 ✓	0
هـواء نقى جدا	1	1	1	1	1	1-

15- ارجو ان تبين كيف تحب ان تكون انت عامة؟
أدفاء ..... لا تغيير ..✓. ابرد .....

16- هل انت عامة مرتاح مع الجو البيىء المحيط بك بالحجرة؟ نعم ..✓. لا ..... [√]

اذا نعم، فلماذا؟ ..[illegible]..

اذا لا, فلماذا؟ ....

17- اية اضافات/ تعليقات؟ ....

الاستبيان الاول: خاص بسكان مبنى ذو فناء - 97/08/10.

قسم ح: شعورك العام وانطباعك الشخصي وتطلعاتك المستقبلية

ان الاسئلة التالية متعلقة بشعورك العام عن المبنى وانطباعاتك الشخصية وتطلعاتك المستقبلية

1- هل تحب العيش في مبنى به فناء ام بدونه؟ به ✓ بدونه ..... [✓]

اذا كان به، فلماذا؟ للتجمع العائلي وتيسير مراقبة الاطفال بسهولة...

اذا كان بدونه، فلماذا؟ ....

2- هل تستعمل اجهزة التكييف خلال فصل الشتاء؟ نعم ..... لا ✓ [✓]

اذا كان نعم، فلماذا؟ ....

اذا كان لا، فلماذا؟ ...لان الجو لا يحتاج الى اجهزة تكييف لان الجو داخله عادي.

3- عامة، بين الساعة 2:00 - 5:00 مساءا في الشتاء هل عادة متشعر باسترخاء و نوم؟

نعم ..... لا..... [✓]

اذا كان نعم، فلماذا؟ ....

اذا كان لا، فلماذا؟ ....

4- عندما تكون درجة الحرارة الخارجية باردة جدا في الشتاء، هل تحس بان لديك المخزون من المقدرة او الطاقة للاستعمال عندما تحتاجها لتحفزك على العمل؟

نعم ✓ لا..... [✓]

اذا كان نعم، فلماذا؟ ...لان الحرارة في حجرتي دافئة..

اذا كان لا، فلماذا؟ ....

5- هل يعجبك الشكل الداخلي للمبنى الذي تقطنه؟ نعم ✓ لا..... [✓]

اذا كان نعم، فلماذا؟ لانه مريح والتقسيم الجيد (الاماكن الوظيفية) الزخارف والديكور المتناسق مع الجو.

اذا كان لا، فلماذا؟ ....

6- هل تعتقد بان المبنى التقليدي مناسب للسكن لك ولاسرتك؟ نعم ..... لا ✓ [✓]

اذا كان نعم، فلماذا؟ ....

اذا كان لا، فلماذا؟ لان متطلبات العصر الحديث غير موجودة.........................

7- هل تفضل بان تعيش بمبنى تقليدي (به فناء) ام بمبنى حديث؟ به ✓ بدونه..... [✓]

اذا كان به فلماذا؟ للتحكم في حركة الهواء الداخل والخارج وكذلك اضاءة الشمس ودخول الحرارة.

اذا كان بدونه فلماذا؟ ....

8- هل تفضل بان تعيش بمبنى تقليدي (به فناء) من حيث تحصيه علمي ان يقفل بمواد بناء حديثة؟ نعم ✓ لا..... [✓]

اذا كان نعم، فلماذا؟ للخارج [illegible] ~~[illegible]~~ وادخال متطلبات العصر.......

اذا كان لا، فلماذا؟ ....

في حالة اجابتك بنعم في السؤال السابق، فالرجاء ان تجيب على السؤال رقم 9.

9- هل تحب ان يكون الفناء مكشوف (بدون سقف) ام مغلق؟ مفتوح ..... مغلق ✓ (به فتحة)

سبب: [illegible] التحكم في المناخ من حيث الشمس والامطار والغبار والطيور والحشرات والرياح والخ..

الاستبيان الأول: خاص بسكان مبنى دو ... - 10/08/97.

/ يتبع قسم ج.

10- أين تنام عادة في الليل؟ [√]

- في حجرة النوم. [بعض]
- في الفناء. [...]
- في حجرة الضيافة. [...]
- فوق سطح المبنى. [...]

11- هل تستطيع أن تذهب خارج البيت عند الساعة 2:00 - 5:00 مساءً في فصل الشتاء؟

[√] لا..... نعم ✓

إذا كان نعم، فلماذا؟ للعمل أو للضرورة [illegible] كالعمل الفلاحي.........

إذا كان لا، فلماذا؟ ....

12- هل أنت مستمتع بالجو المعيشي والبيئة الخارجية؟ [√] لا..... نعم ✓

إذا كان نعم، فهل هو بسبب:

- أنه لا توجد رياح أو غبار أو أصوات مزعجة: ✓ ([illegible]) ....
- أم أن درجة الحرارة الخارجية مناسبة لك: ✓ ([illegible]) ....
- أم أنه لا توجد رطوبة: ....
- أم هناك أسباب أخرى، هي: ....

13- هل وجدت أن هذه البيئة مناسبة لك لتعيش فيها؟ لا ....
لأن متطلبات هذا العصر غير موجودة [illegible] وتطوره [illegible] الى القناعة.

14- ما هي أهم المكونات التي يجب توفرها في المبنى لكي يكون مناسباً للعيش فيه في مثل هذا الجو البارد الخالي من الطبيعة؟ [illegible] ....
[illegible] وإتباع ذلك على الدوام..........

....

15- هل وجدت هذا الاستبيان مفهوماً وسهل للإجابة عليه؟ [√] لا..... نعم ✓

16- هل جعلك هذا الاستبيان أكثر تفهماً وتقبلاً لطبيعة المبنى الذي تقطنه والبيئة المحيطة له؟

[√] لا..... نعم ✓

17- كيف ترى إمكانية تحسين مثل هذا الاستبيان؟ ....
[illegible] ....
[illegible] ....

18- أرجو التكرم بإضافة أية معلومات أو ملاحظات من شأنها أن تخدم مثل هذا العمل لتحسين الجو الحراري للمباني بالمناطق الحارة؟
إن [illegible] صحراوي [illegible]
[illegible] بارد شديد البرودة [illegible] ....
[illegible] ....

أشكركم كثيراً لمساعدتكم ووقتكم الذي منحتموه لتعبئة هذا الاستبيان

مقدم البحث: منصور علي اعليوة

باحث لنيل درجة الدكتوراة جامعة دي منفورت بليستر/ انجلترا. 10/ 8/ 1997

Questionnaire in Arabic: Sample of New Building

نموذج متعلق بالناحية الصحية و تعهد من الشخص المراد عمل الدراسة معه

<u>أرجو قراءة البيانات التالية بعناية</u>

الشخص الذي يمكن اعتباره معفي من مثل هذا الاختبار في حالة:

- عمره تحت 4 سنوات.
- لديه سقم او مرض معدي.
- لديه حمى.
- لديه تخلف عقلي.
- لديه مرض عصبي.
- لديه مرض سمعي.
- أسقم او قام باجراء عملية جراحية بالعين
- لديه اشعار او اخطار بان به مرض مهني.
- لديه سعال او بصاقا او يعاني من وجود دم في البراز
- لديه ضغط الدم او مرض القلب.
- لديه الام دورية، او متقطعة، او يعاني من تنمل في الأطراف.
- قام باجراء عملية جراحية خلال 6 اشهر ماضية
- تعرض لضربة صقيع، هبوط او ارتفاع في درجة الحرارة، ضربة شمس.
- لديه تشوه او مشاكل في الشرج مثل البواسير.
- يعاني من الربو (الأزمة) او اي مرض صدري.
- لديه مشاكل لتخثر الدم.

الاسم. جلال. أحمد مصطفى. اللبع..........

العمر. ثلاث وعشرون سنة..........

هل انت بصحة جيدة؟ نعم ✓ لا ..... [√]

لو كانت الاجابة بلا، هل تفضلت بتوضيح الأسباب: ....

....

هل سبق وان عانيت من مرض او اصبت بحادث؟ نعم ... لا ✓ [√]

لو كانت الاجابة بنعم، هل تفضلت بشرح ذلك: ....

....

هل انت الان تحت المتابعة الصحية؟ نعم ..... لا ✓ [√]

لو كانت الاجابة بنعم، هل تفضلت بشرح ذلك: ....

....

تعهد

اتعهد انا. جلال. أحمد مصطفى. اللبع بأني لا ارى مانع من اجراء هذا الاختبار طواعية، والمتعلق بدراسة و تسجيل التأثيرات الحرارية الراحة للساحة داخل المباني، وذلك بتاريخ 22/8/1997م.
اني اجبت على الاسئلة السابقة وايضا اعتبر الاجابات صحيحة و ذلك حسب ما لدي من معلومات واعلم بانه قد تساعد في استكمال هذا العمل بالصورة المطلوبة. كذلك فاني اقر بانه قد تم شرح كل ما هو مطلوب مني و فهم جميع الاسئلة. اضافة الى ذلك فانه قد تم شرح وتفهيمي بانه يمكن الانسحاب في اي وقت اشاء و يمكن ان اطالب بعمل الاختبار مرة اخرى. ايضا اتعهد بان التزم بالمحافظة على قواعد العمل الاختباري والمحافظة على سلامة الاجهزة المستعملة للقياسات اللازمة، وبناءا على ما سبق فاني اتعهد بذلك.

توقيع الشخص الخاضع للاختبار: .... توقيع الشخص القائم بالاختبار: ....

التاريخ: 22/8/1997م التاريخ: ...../...../1997م

نموذج متعلق بالملابس التي ترتديها

أرجو منك مشكورا تعبئة النموذج المعد لغرض معرفة نوع الملابس التي ترتديها عادة حسب الامكانية والمعلومات التي لديك وان كانت هناك أية ايضاحات تريدها أو أية استفسارات فأرجو عدم التردد في السؤال عنها.

نوع المبنى : مبنى به فناء ...... مبنى حديث ...✓ [√]

الفصل: صيف ✓.. شتاء ...... التاريخ 22/9/1997.

الاسم : ...[illegible] أحمد مصطفى [illegible]...........................

الجنس: ذكر ...✓. أنثى....... [√]

تاريخ الميلاد: 16/7/1973

الارتفاع: 1.85 م

الوزن: 75 كلجم

الملابس المستعملة:

أرجو التكرم بكتابة أو تحديد نوع الملابس التي عادة ترتدونها في مثل هذا الشهر.

قماش التنورة (النساء) أو البنطلون (الرجال): [illegible]..............................

الملابس التقليدية أو القديمة: ... [illegible]..............................

....

الجوارب: ...[illegible] ([illegible])..............................

سروال (تحت قميص): ...[illegible]..............................

الجزء العلوي من الحذاء: ...[illegible] ([illegible])

الجزء السفلي من الحذاء: ...[illegible]..............................

أية اضافات أخرى: ...[illegible]..............................

....

....

....

/الاستبيان الثاني: خاص بسكان مبنى جديد - 97/08/10.

الاستبيان الثاني: خاص بسكان مبنى جديد

هذا الجزء أعتبر على انه خاص بفصل الصيف فقط

تقيم معيشي

اسم المشروع: ....
اسم جاري المقابلة: ....
التاريخ: ....
رقم القطعة: ....
الاتجاه: ....
اسم المقيم أو الساكن (الزوج او الزوجة او اي شخص اخر): جبريل أحمد مصطفى القرع
المكان: مدينة: ✓ .... قرية: .... مدينة جديدة ....

قسم أ : معلومات عامة

1- ما عدد أفراد أسرتك؟ ذكور: 6 اناث: 7
2- ما أعمار افراد أسرتك؟ كبار 20، 44، 55، 22، 21، 26، 28، 27 ... صغار (أقل من 18 سنة) 13، 15
3- منذ متى سكنت في هذا الحي؟ سنوات 20 أشهر ....
4- منذ متى سكنت في هذا المبنى؟ سنوات 15 أشهر ....
5- هل أنت مالك أو مؤجر لهذا المبنى؟ مالك ✓ مؤجر ....
6- هل لديك مبنى أخر (مبنى حديث) ؟ نعم ..... لا ✓ [√]
اذا نعم، هل مازلت تسكنه ؟ نعم ✓ لا ......
اذا لا، فلماذا لاتسكنه؟ ....
....
7- كم ساعة في اليوم عادة ما تبقى داخل المبنى ؟ 12 ساعة
8- كم عدد ادوار المبنى؟ 1 ..... 2 ✓ 3 ..... أو أكثر ......
9- كم عدد غرف النوم بالمبنى؟ 1 ..... 2 ..... 3 ✓ اذا أكثر من ذلك فكم العدد ؟ 6
10- كم عدد الحمامات بالمبنى؟ 1 ..... 2 ✓ 3 4
11- هل لديك أية أجهزة ميكانيكية للتهوية ؟ نعم ✓ لا ...... [√]
ما هي؟ (مثلا : مروحة مكتبية ,مروحة هوائية بالسقف , أو مكيف هواء) مكتبية، مروحة، مكيف هواء
وأين؟ (مثلا : بغرفة النوم , بالمطبخ و الخ) المطبخ، الصالة ...
أية ملاحظات اخرى ؟ ....
....

الاستبيان الثاني: خاص بسكان مبنى دو نسانة - 97/08/10.

قسم ب: التفاعل الاجتماعي

أرجو التكرم باختيار المعدل المناسب الخاص بك على حسب المقياس الموضح لك، عندما يطلب منك ذلك. علما بأن 3 هو متوسط المقياس.

1- كم تبعد المسافة بينك و بين اقرب جار لك بالحي؟
قريب جدا" 1+ 2 3 4 5- بعيد جدا"

2- كم مرة تتحدث و تلتقي بجارك؟
كل يوم 1+ 2 3 4 5- ولا مرة

3- هل تعتقد بانه يمكنك ان تعتمد على اي شخص بالحي الذي تسكنه عندما تحتاج لمساعدة؟
بكل تاكيد 1+ 2 3 4 5- لا يمكن ابدا"

4- هل تعتمد اكثر على اقاربك أم على اصدقائك بالاحياء الأخرى عندما تحتاج لمساعدة؟
نعم ✓ لا ..... [√]

5- هل تعرف جيرانك قبل ان تنتقل لهذا المبنى؟ نعم ✓ لا ..... [√]
اذا نعم، لمن هم؟ اقارب ✓ اصدقاء ..... أخرين، ارجو التوضيح .....

6- كم اسرة تعرف من الجيران حول المبنى الذي تسكنه؟
لاأحد ..... اقل من 5 ..... 5 - 10 ✓ 10-15 ..... اكثر .....

7- كم من الاقارب تعرف من هؤلاء الجيران؟ لاأحد ... اقل من 5 ✓ 5 - 10 ... 10-15 ..... اكثر ...

8- هل زوجتك تشتغل أم هي ربة بيت؟ تشتغل ..... ربة بيت ✓ والدتي

9- هل سكان هذا الحي يمنحون او يوفرون لزوجتك الحرية و الخصوصية المطلوبة التي تحتاجها للتنقل او السير؟
حرية كافية 1+ 2 3 4 5- حرية غير كافية

10- هل تعتقد بانه توجد خطورة على اطفالك للعب خارج المبنى في هذا الحي؟
اوافق تماما 1+ 2 3 4 5- لا اوافق

11- هل تعتقد بان نسبة الجريمة في هذا الحي عالية أم منخفضة؟
عالية 1+ 2 3 4 5- منخفضة

12- ما هي اهم المسببات التي جعلتك تختار ان تسكن في هذا الحي؟
الاصدقاء ..... الاقارب ✓ الجيران ✓ القرب من مكان العمل ..... اقتصاديا .....
الاصدقاء ..... الاقارب ..... الجيران ..... القرب من مكان العمل ..... اقتصاديا .....

13- ما هي الخدمات المتوفرة للسكان بهذا الحي؟
مستشفى/ مستوصف ..... مدرسة ✓ محلات تجارية .....
مكان عام ... جامع ✓ مواصلات عامة .....

14- ما مدى الخصوصية الاجتماعية المتوفرة لك ولاسرتك فيما لو اخذنا بعين الاعتبار الفناء؟
عالية 1+ 2 3 4 5- منخفضة

15- اية ملاحظات اخرى تريد اضافتها: ....
.... [illegible] ....
....

الاسم ...: ... 97/08/10.

قسم ت: الحرارة البيئية والانطباعات الخاصة

ان القيمة البيئية والحالة المرضية والملائمة داخل المبنى لتعكس انطباع يحدد مدى ارتياحك له. لهذا ارجو منك التكرم باختيار المعدل المناسب للمبنى الخاص بك على حسب المقياس الموضح. على ان تختار [/]. علما بان 3 هو متوسط المقياس.

	عموما، هل تحب او ترغب بال...	كم هو مهم للمبنى الذي تقطنه
	5 احب و ارغب جدا / 4 ارغب / 3 محايد/معتدل / 2 غير راغب / 1 غير راغب اطلاقا	5 مهم جدا / 4 مهم / 3 محايد/معتدل / 2 غير مهم / 1 غير مهم اطلاقا
1- ... المنظر الخارجي	3	5
2- . تصميم المبنى	4، 2	5
3- ... الجو بصفة عامة	4	4

ملاحظات/ تعليقات: ...[illegible]...

4- هذا الجزء لتقييم او تحديد مستوى او معدل ترميم المبنى، لذلك:
- كم مرة قمت بترميم مسكنك؟ ...[illegible]...
- من قام بترميمه؟ ...[illegible]...
- هل كان ترميمه سهلا؟ ...نعم...

5- هل انت مرتاح للمبنى ككل؟ ولماذا؟ وما هو الذي اعجبك به اكثر؟ ...نعم مرتاح... [illegible]

6- هذا السؤال متعلقا بتحديد او تقييم البيئة الخارجية المحيطة بك بصورة عامة:
- هل وجدت ان البيئة الخارجية المحيطة بك مناسبة للعيش (من حيث الضوضاء، المشهد الجمالي او الزخرفي، الحياة الاجتماعية، الخ) نعم ✓ لا ..... [√]

اذا كانت الاجابة بنعم، فلماذا؟ ..[illegible] البعد عن مركز المدينة [illegible]... [illegible] ... للعيش

اذا كانت الاجابة بلا، فلماذا ...

- اية اضافات اخرى: ...[illegible]...

/الاستبيان الثاني: خاص بسكان مبنى دو فناء – 97/08/10.

قسم ث: الجو المعيشي داخل المبنى ككل

الغرف المحيطة بالمبنى ككل (الضيافة, الجلوس والنوم)

ان الغاية المرجوة من دراسة هذه المنطقة هى تحليل القيمة او الحالة البيئية والوصول الى اقصى الغايات للسكان وذلك باستعمالهم الغرف المحيطة بذلك الفناء. لهذا ارجو التكرم باختيار المعدل الدال او المناسب لتقييم تلك الغرفة بكتابة [/] حسب ما يشير اليه المقياس المعد لذلك, حيث ان 3 هو متوسط ذلك المقياس.

ملاحظة: الاسئلة من 1 الى 11 متعلقة بحجرة الضيافة فقط

	عموما, هل تحب او ترغب بال...					كم هو مهم للمبنى الذى تقطنه				
	ارغب وبشدة	ارغب	محايد/معتدل	غير راغب	غير راغب اطلاقا	مهم جدا	مهم	محايد/معتدل	غير مهم	غير مهم اطلاقا
	5	4	3	2	1	5	4	3	2	1
1- .. مستوى الضجيج				/	/	/				
2- ... الاضاءة الطبيعية		/	/			/		/		
3- ... الاضاءة الغير طبيعية			/			/		/		
4-... تهوية طبيعية		/					/			
5-... تهوية صناعية	/					/				
6-... كمية الهواء المتحرك			/				/			
7...درجة حرارة الفناء				/			/			
8... مستوى الرطوبة للفناء					/			/		
9-... مستوى الظل داخل الفناء	/					/				
10-... الابواب و النوافذ المطلة على الفناء			/				/	/		
11-... الابواب و النوافذ المطلة على الخارج			/				/	/		

ملاحظات/ تعليقات: ....
....

الاستبيان الشخصي: حاضر سكان مسير دو مساء – 97/08/10.

/ بنيع قسم ث, المنطقة الثانية

ملاحظة: الاسئلة من 12 الى 24 متعلقة بحجرة النوم فقط
ارجو التكرم باختيار المعدل الدال او المناسب لتقييم تلك الغرفة بكتابة [/] حسب ما يشير اليه المقياس المعد لذلك, حيث ان 3 هو متوسط ذلك المقياس.

	عموما, هل تحب او ترغب بال...					كم هو مهم للمبنى الذي تقطنه				
	ارغب و بشدة	ارغب	محايد/متعادل	لا ارغب	لا ارغب اطلاقا	مهم جدا	مهم	محايد/متعادل	غير مهم	غير مهم اطلاقا
	5	4	3	2	1	5	4	3	2	1
12- مستوى الضجيج					/	/				
13- الاضاءة الطبيعية		/				/				
14- الاضاءة الغير طبيعية		/					/			
15- تهوية طبيعية	/					/				
16- تهوية صناعية		/				/				
17- كمية الهواء المتحرك	/					/				
18- درجة حرارة الفناء		/				/				
19- مستوى الرطوبة للفناء			/					/		
20- مستوى الظل داخل الفناء	/		/			/		/		
21- الابواب و النوافذ المطلة على الفناء			/					/		
22- الابواب و النوافذ المطلة على الخارج			/					/		

ملاحظات/ تعليقات ....
....

23- ارجو اختيار احد المربعات التي تعبر عن مدى احساسك بالحرارة داخل الفناء في هذا الفصل:

ولا مرة	اقل من 5 ايام	5-10 ايام	10-20 يوما	20-30 يوما	اكثر من 30	كل الفصل

24- ارجو اختيار احد المربعات التي تعبر عن مدى احساسك بالبرودة داخل الفناء في هذا الفصل:

ولا مرة	اقل من 5 ايام	5-10 ايام	10-20 يوما	20-30 يوما	اكثر من 30	كل الفصل

/الاخصائي: حامد بسكان مبنى ذو فناء - 97/08/10.

/ يتبع قسم ث, المنطقة الثانية

ملاحظة: الاسئلة من 25 الى 37 تعلقة بحجرة الجلوس فقط
ارجو التكرم باختيار المعدل الدال او المناسب لتقييم تلك الغرفة بكتابة [/] حسب ما يشير اليه المقياس المعد لذلك, حيث ان 3 هو متوسط ذلك المقياس.

	عمومًا, هل تحب او ترغب بال...					كم هو مهم للمبنى الذى تقطنه				
	غير راغب اطلاقا	غير راغب	محايد/متعادل	ارغب	ارغب و بشدة	غير مهم اطلاقا	غير مهم	محايد/متعادل	مهم	مهم جدا
	1	2	3	4	5	1	2	3	4	5
25- .. مستوى الضجيج	/									/
26- ... الاضاءة الطبيعية			/						/	
27- الاضاءة الغير طبيعية				/						/
28-... تهوية طبيعية				/					/	
29-... تهوية صناعية					/					/
30-... كمية الهواء المتحرك					/				/	
31-...درجة حرارة الفناء			/					/		
32-... مستوى الرطوبة للفناء			/					/		
33-... مستوى الظل داخل الفناء				/					/	
34-... الابواب و النوافذ المطلة على الفناء			/					/		
35-... الابواب و النوافذ المطلة على الخارج			/					/		

ملاحظات/تعليقات: ....
....

36- ارجو اختيار احد المربعات التى تعبر عن مدى احساسك بالحرارة داخل الفناء فى هذا الفصل:

ولا مرة	اقل من 5 ايام	5-10 ايام	10-20 يوما	20-30 يوما	اكثر من 30 /	كل الفصل

38- ارجو اختيار احد المربعات التى تعبر عن مدى احساسك بالبرودة داخل الفناء فى هذا الفصل:

ولا مرة	اقل من 5 ايام	5-10 ايام /	10-20 يوما	20-30 يوما	اكثر من 30	كل الفصل

الاســتـبـيـانـالـنـفـسـي: خـاص بـمـسـكـان مـبـنـى ذو طـ - 97/03/19.

قـسـم ج: الـجـو او الـمـعـدل الـحـراري الـمـنـاسـب

ارجو التكرم بالاجابة على الاسئلة التالية والمتعلقة بتقييم الجو الحراري المناسب وذلك باختيارك المعدل الدال او المناسب لتقييم المبنى ككل حسب مايشير اليه المقياس او المعيار المعد لذلك بكتابة [/]. حيث ان 3 هو متوسط ذلك المقياس.

1- ارجو ان تشير او تبين نوع الحجرة التي انت بها الان في المربع التالي:

[illegible]

2- في هذه الحجرة التي انت بها الان, ارجو ان تبين على المقياس التالي كيف تشعر انت الان!

غير مرتاح اطلاقا	4	جاف جدا	4	رطوبة شديدة	4	تيار هوائي شديد	4
غير مرتاح	3	جاف	3	رطوبة	3	تيار هوائي	3
مرتاح قليلا	2	جاف قليلا	2	رطوبة قليلة	2 /	تيار هوائي قليل	2
مرتاح جدا	1 /	غير جاف	1 /	لا توجد رطوبة	1	لا يوجد تيار هوائي	1 /

3- ارجو ان تبين على المقياس التالي كيف تشعر أنت الان!

حار	3
دافيء	2
دافيء قليلا	1 /
محايد/ متعادل	0
بارد قليلا	-1
بارد باعتدال	-2
بارد جدا	-3

4- ارجو ان تبين على المقياس التالي كيف تشعر بنسمة الهواء أنت الان!

هواء ملوث كثير	5
هواء ملوث	4
محايد/ متعادل	3
هواء نقي	2 /
هواء نقي جدا	1

5- ارجو ان تبين على المقياس التالي كيف تريد ان تكون أنت الان!

أدفاء ..... لا تغيير ..... ابرد /..

6- هل تشعر أنت الان سواء ببرودة او حرارة في اى جزاء من جسمك؟

نعم /.. لا ..... [√] بارد ..... دافيء /..

اذا اجابتك بنعم, فأين؟ الرأس /.. الكتفين /.. البدن .... الذراعين ...

فوق الركبة ..... تحت الركبة ..... القدمين .....

هل شعورك هذا غير مريح لك؟ نعم /.. لا ..... [√]

7- هل لاحظت اية حركة للهواء؟ نعم /... لا /.. [√]

اذا نعم, فأين؟ بالوجه /.. بالرقبة .... باليدين /.. بالقدمين .....

هل شعورك هذا غير مريح لك؟ نعم /.. لا /.. [√]

8- هل انت الان مرتاح مع الجو البيىء المحيط بك بالحجرة؟ نعم /.. لا ..... [√]

اذا نعم, فلماذا؟ [illegible]

[illegible]

اذا لا, فلماذا؟ ....

....

الاستبيان الثاني: خاص بسكان مبنى دو الفناء - 97/08/10.

/ يتبع قسم ج.

9- كيف تشعر (انت) عامة وانت تعيش داخل هذا المبنى وبهذا التصميم و التنفيذ القائم الان؟

	5	4	3	2	1	
جميل		✓				قبيح
استرخاء	✓					توتر
نشاط			✓			كسل

10- بالاستناد الى التصميم الذى هو عليه مسكنك ارجو ان تبين على المقياس الحرارى كيف تشعر انت عامة

		بكل المبنى	بالفناء	بحجرة الضيافة	بحجرة النوم	بالمطبخ	بالحمام
غير مرتاح اطلاقا	4						
غير مرتاح	3				✓		
مرتاح قليلا	2	✓	✓	✓		✓	✓
مرتاح جدا	1						

11- ارجو ان تبين على المقياس التيار الهوائى الذى يدل عن كيفية شعورك انت عمة.

		بكل المبنى	بالفناء	بحجرة الضيافة	بحجرة النوم	بالمطبخ	بالحمام
تيار هوائى شديد	4						
تيار هوائى	3						
تيار هوائى قليل	2	✓	✓		✓	✓	✓
لا يوجد تيار هوائى	1			✓			✓
ارجو ان تختار المربع (ات) المناسب اذا كنت لا تشعر بارتياح		☐	☐	☐	☒	☐	☐

12- ارجو ان تبين على المقياس الرطوبة الذى يدل عن كيفية شعورك انت عمة.

		بكل المبنى	بالفناء	بحجرة الضيافة	بحجرة النوم	بالمطبخ	بالحمام
رطوبة شديدة	4						
رطوبة	3						
رطوبة قليلة	2					✓	✓
لا توجد رطوبة	1	✓	✓	✓	✓		
ارجو ان تختار المربع (ات) المناسب اذا كنت لا تشعر بارتياح		☐	☐	☐	☐	☐	☐

الاستبيان الثاني: صامي بمسكن مبنى دو ستتاد - 97/08/10.

/يتبع لسج.

13- بالاشارة الى التصميم المنفذ عليه المبنى ارجو ان تبين على المقياس التالي كيف تشعر انت عامة.

	بكل المبنى	بالفناء	بحجرة الضيافة	بحجرة النوم	بالمطبخ	بالحمام
حار	3	3	3	3 ✓	3 ✓	3
دافي	2	2	2	2	2	2
دافي قليلا	1	1	1 ✓	1	1	1
محايد/متعادل	0 ✓	0 ✓	0	0	0	0 ✓
بارد قليلا	-1	-1	-1	-1	-1	-1
بارد باعتدال	-2	-2	-2	-2	-2	-2
بارد جدا	-3	-3	-3	-3	-3	-3

14- ارجو ان تبين على مقياس نسبة الهواء التالي والذي يوضح كيفية شعورك انت عامة.

	بكل المبنى	بالفناء	بحجرة الضيافة	بحجرة النوم	بالمطبخ	بالحمام
هواء ملوث كثير	5	5	5	5	5	3
هواء ملوث	4	4	4	4	4	2
محايد/متعادل	3	3	3	3	3 ✓	1 ✓
هواء نقي	2 ✓	2 ✓	2 ✓	2 ✓	2	0
هواء نقي جدا	1	1	1	1	1	-1

15- ارجو ان تبين كيف تحب ان تكون انت عامة؛
ادفاء . ... لا تغيير ..... ابرد ..✓.

16- هل انت عامة مرتاح مع الجو البيئي المحيط بك بالحجرة؟ نعم ✓. لا ✓ [√]

اذا نعم، فلماذا؟ ..نظراً لأن الجو جاء بتدفئة طبيعية وعدم وجود أي سبب..........
للمزعجات كالضوضاء وغيرها..
اذا لا، فلماذا؟ ....
....

17- اية اضافات/تعليقات!..
....
....
....

الاستبيان الثاني: خاص بسكان مبنى ذو فناء – 97/08/10.

قسم ح: شعورك العام وانطباعك الشخصي وتطلعاتك المستقبلية

ان الاسئلة التالية متعلقة بشعورك العام عن المبنى وانطباعاتك الشخصية وتطلعاتك المستقبلية

1- هل تحب العيش بمبنى به فناء ام بدونه؟ به ..... بدونه ..... [√]

اذا كان به، فلماذا؟ ....

اذا كان بدونه، فلماذا؟ ...[illegible]...

2- هل تستعمل اجهزة التكييف خلال فصل الصيف؟ نعم ..... لا ..... [√]

اذا كان نعم، فلماذا؟ ...[illegible]...

اذا كان لا، فلماذا؟ ....

3- عادة، بين الساعة 2:00 – 5:00 مساءا في الصيف هل عادة ماتشعر بالاسترخاء و نوم؟

نعم ..... لا ..... [√]

اذا كان نعم، فلماذا؟ ...[illegible]...

اذا كان لا، فلماذا؟ ....

4- عندما تكون درجة الحرارة الخارجية مرتفعة جدا في الصيف، هل تجد بان لديك المخزون من المقدرة او الطاقة للاستعمالها عندما تحتاجها لتحفزك على العمل؟

نعم ..... لا ..... [√]

اذا كان نعم، فلماذا؟ ....

اذا كان لا، فلماذا؟ ...[illegible]...

5- هل يعجبك الشكل الداخلي للمبنى الذى تقطنه؟ نعم ..... لا ..... [√]

اذا كان نعم، فلماذا؟ ...[illegible]...

اذا كان لا، فلماذا؟ ....

6- هل تعتقد بان المبنى التقليدي مناسب للسكن لك ولاسرتك؟ نعم ..... لا ..... [√]

اذا كان نعم، فلماذا؟ ....

اذا كان لا، فلماذا؟ ...[illegible]...

7- هل تفضل بان تعيش بمبنى تقليدي (به فناء) ام بمبنى حديث؟ نعم ..... تقليدي لا ..... حديث [√]

اذا كان نعم تقليدي، فلماذا؟ ....

اذا كان لا حديث، فلماذا؟ ...[illegible]...

8- هل تفضل بان تعيش بمبنى تقليدي (به فناء) من حيث تصميمه على ان يعد بمواد بناء حديثة؟ نعم ..... لا ..... [√]

اذا كان نعم، فلماذا؟ ....

اذا كان لا، فلماذا؟ ...[illegible]...

في حالة اجابتك بنعم في السؤال السابق، فارجو ان تجيب على السؤال رقم 9.

9- هل تحب ان يكون الفناء مفتوح (بدون سقف) ام مغلق؟ مفتوح ..... مغلق .....

السبب: ....

....

/الاستبيان الثاني: خاص بسكان مبنى ذو فناء - 10/08/97.

/ يتبع قسم ج.

10- اين تنام عادة في الليل؟ [√]

- في حجرة النوم. [...]
- في الفناء. [✓]
- في حجرة الضيافة. [...]
- فوق سطح المبنى. [...]

11- هل تستطيع ان تذهب خارج البيت عند الساعة 2:00 - 5:00 مساءً في فصل الصيف؟

نعم ✓. لا..... [√]

اذا كان نعم، فلماذا؟ ...الجو المعتدل [illegible]...

اذا كان لا، فلماذا؟ ......

12- هل انت متمتع بالجو المعيشي والبيئي الخارجي؟ نعم ✓. لا..... [√]

اذا كان نعم، فهل هو بسبب:

- انه لا توجد رياح او غبار او اصوات مزعجة: نعم......
- ام ان درجة الحرارة الخارجية مناسبة لك: نعم......
- ام انه لا توجد رطوبة: ......✓......
- ام هناك اسباب اخرى، هي: [illegible] اجتماعية......

13- هل وجدت ان هذه البيئة مناسبة لك لتعيش فيها؟ ......

......نعم......

14- ما هي اهم المكونات التي يجب توفرها في المبنى لكي يكون مناسبا للعيش فيه في مثل هذا الجو الحار من الطبيعة؟ [illegible]

[illegible]

......[illegible]......

15- هل وجدت هذا الاستبيان مفهوما وسهل للاجابة عليه؟ نعم ✓. لا..... [√]

16- هل جعلك هذا الاستبيان اكثر تفهما وتفهما لطبيعة المبنى الذى تقطنه والبيئة المحاورة له؟

نعم ✓. لا..... [√]

17- كيف ترى امكانية تحسين مثل هذا الاستبيان؟ ......

[illegible]......

......[illegible]......

18- ارجو التكرم باضافة اية معلومات او ملاحظات من شانها ان تخدم مثل هذا العمل لتحسين الجو الحراري للمباني بالمناطق الحارة؟

......

......

......

اشكركم كثيرا لمساعدتكم ووقتكم الذى منحتموه لتعبئة هذا الاستبيان

مقدم البحث: منصور علي اعليوة

باحث لنيل درجة الدكتوراة جامعة دي منتفورت بلستر/ انجلترا. 10/ 8/ 1997

APPENDIX C:

Clothing insulation and metabolic rates

(from ISO 7730)

Appendix C: Clothing and Activity level

Work Clothing	I_{cl} clo	I_{cl} m^2K/W	Daily wear clothing	I_{cl} clo	I_{cl} m^2K/W
U/pants, boiler suit, socks, shoes	0.70	0.110	Panties, T-shirt, shorts, light socks, sandals	0.30	0.050
U/pants, shirt, trousers, socks, shoes	0.75	0.115	Panties, petticoat, stockings, light dress with sleeves, sandals	0.45	0.070
U/pants, shirt, boiler suit, socks, shoes	0.80	0.125	U/pants, short sleeve shirt, light trousers, light socks, shoes	0.50	0.080
U/pants, shirt, trousers, jacket, socks, shoes	0.85	0.135	Panties, stockings, short sleeve shirt, skirt, sandals	0.55	0.085
U/pants, shirt, trousers, smock, socks, shoes	0.90	0.140	U/pants, shirt, light-weight trousers, socks, shoes	0.60	0.095
U/wear (s/sleeves & legs) shirt, trousers, jacket, socks, shoes	1.00	0.155	Panties, petticoat, stockings, dress, shoes	0.70	0.105
U/wear (s/sleeves & legs) shirt, trousers, boiler suit, socks, shoes	1.10	0.170	U/wear, shirt trousers, socks, shoes	0.70	0.110
U/wear (l/sleeves & legs), thermojacket, socks, shoes	1.20	0.185	U/wear, track suit, long socks, runners	0.75	0.115
U/wear (s/sleeves & legs), shirt, trousers, jacket, thermojacket, socks, shoes	1.25	0.190	Panties, petticoat, shirt, skirt, thick knee-socks, shoes	0.80	0.120
U/wear (s/sleeves & legs), boiler suit, thermojacket and trousers, socks, shoes	1.40	0.220	Panties, shirt, skirt, round neck sweater, thick knee-socks, shoes	0.90	0.140
U/wear (s/sleeves & legs), shirt, trousers, jacket, thermojacket & trousers, socks, shoes	1.55	0.225	U/pants, s/sleeve singlet, shirt, trousers, V-neck sweater, socks, shoes	0.95	0.145
U/wear (s/sleeves & legs), shirt, trousers, jacket, heavy quilted outer jacket & overalls, shoes	1.85	0.285	Panties, shirt, trousers, jacket, socks, shoes	1.00	0.155
U/wear (s/sleeves & legs), shirt, trousers, jacket, heavy quilted jacket overalls, socks, shoes, cap, gloves	2.00	0.310	Panties, stockings, shirt, skirt, vest, jacket	1.00	0.155
U/wear (l/sleeves & legs), thermo-jacket & trousers, outer thermo-jacket & trousers, socks, shoes	2.20	0.340	Panties, stockings, blouse, long skirt, jacket, shoes	1.10	0.170
U/wear (l/sleeves & legs), thermo-jacket & trs, quilted parka, quilted overalls, socks, shoes, cap, gloves	2.55	0.395	U/wear, singlet (s/sleeves), shirt, trousers, jacket, socks, shoes	1.10	0.170
			U/wear, singlet (s/sleeves), shirt, trousers, vest, jacket, socks, shoes	1.15	0.180
			U/wear (l/sleeves & legs), shirt, trousers, V-neck sweater, jacket, socks, shoes	1.30	0.200
			U/wear (s/sleeves & legs), shirt, vest trousers, jacket, coat, socks, shoes	1.50	0.230

Metabolic rates of different activities

Further information on metabolic rates is given in ISO 8996.

Table A.1 — Metabolic rates

Activity	Metabolic rates W/m²	Metabolic rates met
Reclining	46	0,8
Seated, relaxed	58	1,0
Sedentary activity (office, dwelling, school, laboratory)	70	1,2
Standing, light activity (shopping, laboratory, light industry)	93	1,6
Standing, medium activity (shop assistant, domestic work, machine work)	116	2,0
Walking on the level:		
2 km/h	110	1,9
3 km/h	140	2,4
4 km/h	165	2,8
5 km/h	200	3,4

APPENDIX D:

Sample of data collected

Appendix D: Sample of data collected from field survey in Ghadames, 1997-98

Old Traditional NV Building

(see Figure 7.2, Chapter 7)

DAY	TIME	Tin	M.B.R.T	Tout
15/08/97	19:00:00	32.15	32	32.35
15/08/97	20:00:00	31.9	31.8	31.2
15/08/97	21:00:00	31.5	31.2	29.475
15/08/97	22:00:00	31.175	31.25	28.175
15/08/97	23:00:00	30.9	31.4	26.55
16/08/97	00:00:00	30.6	30.775	26.275
16/08/97	01:00:00	30.3	29.775	25.75
16/08/97	02:00:00	29.975	29.05	25.175
16/08/97	03:00:00	29.6	28.35	24.025
16/08/97	04:00:00	29.2	27.825	23.15
16/08/97	05:00:00	28.925	27.475	22.45
16/08/97	06:00:00	28.675	27.45	21.8
16/08/97	07:00:00	28.375	26.85	21.325
16/08/97	08:00:00	28.1	26.45	21.65
16/08/97	09:00:00	28.325	26.675	24.275
16/08/97	10:00:00	29.075	28.275	30
16/08/97	11:00:00	30.525	30.3	34.475
16/08/97	12:00:00	31.2	31.625	37.4
16/08/97	13:00:00	31.925	32.225	40
16/08/97	14:00:00	32.15	32.575	41.75
16/08/97	15:00:00	32.65	33.3	40.95
16/08/97	16:00:00	32.75	34.05	39.625
16/08/97	17:00:00	32.65	33.85	42.6
16/08/97	18:00:00	32.55	33.9	40.475

New Contemporary AC Building

(see Figure 7.3, Chapter 7)

DAY	TIME	Tin	M.B.R.T	Tout
15/08/97	19:00:00	34.4	33.6	34.9
15/08/97	20:00:00	33.95	33.7	33.125
15/08/97	21:00:00	33.35	33.675	31.85
15/08/97	22:00:00	32.65	33.425	30.55
15/08/97	23:00:00	32.2	33.225	29.55
16/08/97	00:00:00	31.85	33.175	28.725
16/08/97	01:00:00	31.175	33.025	27.45
16/08/97	02:00:00	31.15	32.825	26.675
16/08/97	03:00:00	30.55	32.625	25.6
16/08/97	04:00:00	30.35	32.35	24.775
16/08/97	05:00:00	29.95	32.075	24.575
16/08/97	06:00:00	29.525	31.8	24.225
16/08/97	07:00:00	29.2	31.55	24.5
16/08/97	08:00:00	29.975	30.725	25.675
16/08/97	09:00:00	30.675	31.35	31.65
16/08/97	10:00:00	32.3	31.825	36.825
16/08/97	11:00:00	33	31.975	39.975
16/08/97	12:00:00	33.25	32.325	41.725
16/08/97	13:00:00	32.95	32.35	43.8
16/08/97	14:00:00	33	32.775	45.6
16/08/97	15:00:00	32.75	33.7	47.15
16/08/97	16:00:00	33.175	34.125	48.425
16/08/97	17:00:00	33.775	33.975	47.45
16/08/97	18:00:00	34.8	34.325	44.1

APPENDIX E:

Programme for second field work in Ghadames

Appendix E:

Programme for Second Field work Research in Ghadames/ Libya, July- August, 1998.